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A . Report Title: Report on Quality Control Review of DELOITTE & TOUCHE LLP Office of Management and Budget Circular A-133 Audit Report of Carnegie Mellon University, Fiscal Year Ended June 30, 1999

B. DATE Report Downloaded From the Internet: 12/20/01

C. Report's Point of Contact: (Name, Organization, Address, Office Symbol, & Ph #): **OAIG-AUD (ATTN: AFTS Audit Suggestions)**
Inspector General, Department of Defense
400 Army Navy Drive (Room 801)
Arlington, VA 22202-2884

D. Currently Applicable Classification Level: Unclassified

E. Distribution Statement A: Approved for Public Release

F. The foregoing information was compiled and provided by:
DTIC-OCA, Initials: __VM__ **Preparation Date 12/20/01**

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INTERNET DOCUMENT INFORMATION FORM

A . Report Title: Best Manufacturing Practices: Report of Survey Conducted at Raytheon Missile Systems Company, Tucson, AZ

B. DATE Report Downloaded From the Internet: 12/20/01

C. Report's Point of Contact: (Name, Organization, Address, Office Symbol, & Ph #): **Best Manufacturing Practices**
Center of Excellence
College Park, MD

D. Currently Applicable Classification Level: Unclassified

E. Distribution Statement A: Approved for Public Release

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REPORT OF SURVEY CONDUCTED AT

RAYTHEON MISSILE SYSTEMS COMPANY
TUCSON, AZ
SEPTEMBER 1998

Best Manufacturing Practices

1998 Award Winner

INNOVATIONS IN AMERICAN GOVERNMENT

BEST MANUFACTURING PRACTICES CENTER OF EXCELLENCE
College Park, Maryland
www.bmpcoe.org

Foreword

This report was produced by the Office of Naval Research's Best Manufacturing Practices (BMP) program, a unique industry and government cooperative technology transfer effort that improves the competitiveness of America's industrial base both here and abroad. Our main goal at BMP is to increase the quality, reliability, and maintainability of goods produced by American firms. The primary objective toward this goal is simple: to identify best practices, document them, and then encourage industry and government to share information about them.

The BMP program set out in 1985 to help businesses by identifying, researching, and promoting exceptional manufacturing practices, methods, and procedures in design, test, production, facilities, logistics, and management – all areas which are highlighted in the Department of Defense's 4245.7-M, *Transition from Development to Production* manual. By fostering the sharing of information across industry lines, BMP has become a resource in helping companies identify their weak areas and examine how other companies have improved similar situations. This sharing of ideas allows companies to learn from others' attempts and to avoid costly and time-consuming duplication.

BMP identifies and documents best practices by conducting in-depth, voluntary surveys such as this one at Raytheon Missile Systems Company, Tucson, Arizona conducted during the week of September 14, 1998. Teams of BMP experts work hand-in-hand on-site with the company to examine existing practices, uncover best practices, and identify areas for even better practices.

The final survey report, which details the findings, is distributed electronically and in hard copy to thousands of representatives from industry, government, and academia throughout the U.S. and Canada – *so the knowledge can be shared.* BMP also distributes this information through several interactive services which include CD-ROMs, BMPnet, and a World Wide Web Home Page located on the Internet at http://www.bmpcoe.org. The actual exchange of detailed data is between companies at their discretion.

Raytheon Missile Systems Company is the world's premier producer and developer of tactical missile systems, including the Advanced Medium Range Air-to-Air Missile, Phalanx, Stinger, Rolling Airframe Missile, and Tomahawk. This plant site is the only facility in the country that can produce fully-assembled missiles from start to finish for all U.S. and allied military customers. Among the best examples were Raytheon Missile Systems Company's accomplishments in rapid prototyping; wargaming laboratory; flexible work cells; hybrid microelectronic assembly; remediation control room; advanced modular factory; agile improvement process; integrated process architecture; technology roadmaps; unified community advisory board; Knowledge Center Southwest; and Raytheon Missile Systems Company University.

The Best Manufacturing Practices program is committed to strengthening the U.S. industrial base. Survey findings in reports such as this one on Raytheon Missile Systems Company expand BMP's contribution toward its goal of a stronger, more competitive, globally-minded, and environmentally-conscious American industrial program.

I encourage your participation and use of this unique resource.

Ernie Renner
Director, Best Manufacturing Practices

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Section 1

Report Summary

Background

In 1922, Laurence K. Marshall and Vannevar Bush joined forces with Charles G. Smith who had developed a prototype for a home refrigerator using artificial coolants. Together, the young entrepreneurs founded the American Appliance Company with dreams of prosperity. Unfortunately, the product was a bust and never left the laboratory. Facing failure, Marshall and Bush suggested revisiting an earlier idea of Smith's: a new kind of gaseous tube that enabled radios to operate on electricity, rather than batteries, by plugging them into a wall socket. This gaseous rectifier was perfected in 1925, and marketed under the brand name Raytheon — meaning *a beam of light* (rai) *from the gods* (theon). Also that year, the company officially became the Raytheon Manufacturing Company due to another's claim on the original name.

Since the 1920s, the company has diversified and expanded its operations into the defense sector. Strategic acquisitions and mergers also helped strengthen Raytheon's innovative capabilities, and added to its legacy of technological advancements. Among these were the first commercial microwave oven (Amana Radarange); miniature tubes for hearing aids; the first electronic depth sounder (Fathometer); mass production of magnetron tubes; early shipboard radar; the first missile guidance system (Lark) that could hit a flying target; a space communications system for Apollo XI; mobile radio telephones; the first combat-proven air defense missile system; and the Terminal Doppler Weather Radar.

Today, the Raytheon Company is a global technology leader that operates in three core business segments: defense and commercial electronics; business aviation and special mission aircraft; and engineering and construction. The corporation is headquartered in Lexington, Massachusetts; employs more than 100,000 employees worldwide; and achieved $20 billion in revenues for 1997. The BMP survey focused on Raytheon's Defense Systems Segment, specifically the Raytheon Missile Systems Company (RMSC) in Tucson, Arizona. This facility was originally established in 1951 by Howard Hughes to produce the Falcon, the world's first air-to-air radar guided missile. Raytheon acquired the plant site through its 1997 merger with Hughes Missile Systems. Currently, RMSC employs approximately 8,800 personnel, and achieved $2.1 billion in sales for 1997.

RMSC is the world's premier producer and developer of tactical missile systems, including the Advanced Medium Range Air-to-Air Missile, Phalanx, Stinger, Rolling Airframe Missile, and Tomahawk. The Tucson plant is the only facility in the country that can produce fully-assembled missiles from start to finish for all U.S. and allied military customers. RMSC uses an agile manufacturing approach to anticipate and respond to the changing marketplace and its customers' needs, while increasing affordability, performance, quality, and technology innovation. As a result of its efforts, this facility won the Arizona Pioneer Award for Quality in 1994 and the Arizona Governor's Award for Quality in 1997. Among the best practices documented were RMSC's rapid prototyping; wargaming laboratory; flexible work cells; hybrid microelectronic assembly; remediation control room; advanced modular factory; agile improvement process; integrated process architecture; technology roadmaps; unified community advisory board; Knowledge Center Southwest; and Raytheon Missile Systems Company University.

Although the founders of Raytheon were dreamers, they could never have imagined the extent to which their company would actually contribute to shaping the 20th century. Raytheon's pioneering efforts created a legacy of excellence and innovation. Continuing in this tradition, the company is striving to strengthen its competitiveness; advance its high standard of performance and dependability; and enrich its vision for the next century. The BMP survey team considers the following practices to be among the best in industry and government.

Best Practices

The following best practices were documented at RMSC:

Item	Page
Boundary Scan Test	**15**
The test engineers and circuit/product designers at RMSC's Electronic and Product Design Center work concurrently during the early stages of product design to maximize usage of new digital design testability and test techniques. The Center's latest technique is the Boundary Scan Test, which combines digital circuit design, design for test/testability, and prototype test functions.	

Information

The following information items were documented at RMSC:

Design Standards for Pro/Engineer

RMSC implemented standard design modeling practices so that Pro/Engineer modeling software can be effectively used throughout the company. This standardization fosters a "Design Anywhere, Build Anywhere" philosophy.

Key Characteristic Designation System

RMSC implemented the Key Characteristic Designation System. This system focuses on key product characteristics, and attempts to control excessive variation in product features.

Russian Electroflotation Technology Partnership

RMSC has formed a promising partnership with the U.S. Air Force and Russia's Mendeleyev University of Chemical Technology. The partnership's objective is to develop a full-scale working model of a Russian-developed and Eastern European-utilized technology for treating complex organic and other synthetic compounds in wastewater.

Six Sigma Robust Design Process

RMSC's Product, Process, and Performance Improvement Group has begun implementing six sigma process controls into the company's early design cycles via the Six Sigma Robust Design process. This customer-focused, quality improvement discipline is expected to provide a framework for significantly reducing defects in key products and processes.

Team of Teams

In January 1998, RMSC implemented the Team of Teams approach as a way to adapt commercial practices for designing and building military hardware with commercial components. This approach uses multi-functional teams of experts from across RMSC.

Accident Boards and Fairs

RMSC developed several Environmental, Health and Safety programs designed to increase employee and management awareness. Two of these programs are the Lost Time Accident Board, and the Environmental, Health and Safety Fair.

Best Value Analysis for Procurement

In 1991, RMSC implemented Best Value Analysis for Procurement to simplify and validate its vendor selection process. This system provides historical data from the Supplier Performance Rating System, which is accessible by commodity, part number, or vendor.

Certified Supplier Program

In 1991, RMSC initiated the Certified Supplier program to reduce the costs and cycle times of its receiving and inspection processes. The program also addressed costs associated with travel, source inspectors, duplicate receiving inspections, and nonconforming material/corrective action activities.

Corrective and Preventive Action Teams

RMSC established Corrective and Preventive Action Teams to proactively address methods for reducing non-conformances. These teams also enable RMSC to support information technology and agile manufacturing initiatives.

Cycle Inventory

Per Federal Acquisition Regulation, Part 45, RMSC needed to establish a means of controlling and verifying inventory accuracy levels, as described in the Department of Defense's Material Management Accounting Standards. In 1987, RMSC initiated the Cycle Inventory process to comply with this regulation, and to provide scheduling accuracy for production.

Diminishing Manufacturing Sources Management

Like other military contractors, RMSC is faced with the ongoing problem of electronic component obsolescence. To address this problem, RMSC developed a Diminishing Manufacturing Sources management strategy to evaluate other avenues for dealing with component obsolescence.

Electronic Soldering

Since acquisition reform became a Department of Defense initiative, soldering at RMSC has changed a great deal. Today, RMSC's Electronic Soldering process is an advanced technology that produces highly reliable solder joints, and uses well-defined requirements, guidelines, and specifications; state-of-the-art equipment; specific materials; controlled processes; excellent skills training; and organized contractor flowdown.

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Section 2

Best Practices

Design

Boundary Scan Test

The test engineers and circuit/product designers at Raytheon Missile Systems Company's (RMSC's) Electronic and Product Design Center work concurrently during the early stages of product design to maximize usage of new digital design testability and test techniques. The Center's latest technique is the Boundary Scan Test (BST), which combines digital circuit design, design for test/testability, and prototype test functions. The BST enables users to employ PC-based assembly verification tests and in-system/on-board programmable capabilities for new designs. Typical programming scenarios include setting up devices (e.g., logic chips, field-programmable gate arrays) with simulation vectors for low speed verification of design simulation in hardware or with synthesized test bench parameters to apply stimulus to a Unit Under Test (UUT) at speed.

The BST function must be designed into a new digital design as a resident part of the microchip circuit. This process involves using the designer's circuit database; completing post processing of the board netlist to a PC platform; applying Boundary Scan Descriptive Language models for compilation; and creating support files via commercial-off-the-shelf (COTS) software tools. Technicians can apply the BST to a UUT by using a Windows 95-based PC, a COTS controller card, and RMSC-designed controller software. The BST provides complete testing capability which can be quickly implemented and placed on-line to test a product's first engineering units. This same test software and test platform can be used in other settings (e.g., engineering laboratory, circuit board assembly facility, production test and rework facility), which significantly reduces costs and improves efficiencies.

RMSC successfully implemented BST practices on its Standard Missile Block IV and AIM-9X programs, which reduced troubleshooting cycle times by a factor of 8:1. Other benefits include eliminating $1.5 million in capital equipment costs and $35,000 in annual recurring costs for automated test system operations; setting up two new digital designs that are 100% in-circuit programmable; and establishing cost effective PC-based circuit ring-out (shorts and opens) in new digital designs.

Centralized Components and Materials Team

By centralizing its Components and Materials team, RMSC established a cadre of collocated experts for grave-to-cradle support in parts, materials, and process disciplines. This approach standardizes all RMSC programs, and replaces the previous method which inconsistently handled component and material problems. The Components and Materials team consists of three groups: Components and Materials Applications; Component and Materials Laboratories; and Computer Aided Design (CAD) Library Support. These groups can provide direct support on specific issues and/or indirect support via the Components Information Management System (CIMS).

Components and Materials Applications — These experts specialize in parts and materials documentation and contract requirements; commercial and military supplier processes; radio frequency, microcircuit and connector applications; non-destructive testing; chemistry, materials science, and metallurgy; composite materials; and surface corrosion. The group maintains the technical accuracy of CIMS, and leads the Parts/Material Management Teams (P/MMTs) in determining the approval status for design standardization. In addition, the group supports the on-line RMSC parts and material request process by determining RMSC preferred parts; validating part numbers; identifying technology maturity level and/or obsolescence; ensuring part availability; verifying supplier statistical process control; and monitoring part reliability.

Component and Materials Laboratories — These experts use extensive state-of-the-art chemical analysis, failure analysis, test, materials, and process equipment/methods (e.g., differential scanning calorimetry, Fourier transform infrared spectroscopy, dynamic mechanical thermal analysis, scanning electron microscopy with energy dispersive spectra analysis, plasma etching, hermicity testing, salt fog, mechanical testing, prototype plating). In addition to providing quick and valuable responses to customers' requests, this group develops and maintains standard processes as well as the associated documentation and metrics.

CAD Library Support — These experts establish the company's standardized symbols, geometries, and simulations. This group is part of the RMSC-wide

effort to integrate processes, and to control and standardize the parts and materials selection. The company funds the development of CAD library components for RMSC preferred parts with overhead monies. Those programs interested in using new or non-preferred parts can do so at their own expense.

The collocation of the Components and Materials team enabled RMSC to easily implement a jointly-developed June 1994 Tri Service/Hughes Directive. As a subset of CIMS and a direct result of the Directive, RMSC established an approved parts and suppliers list; a standard process for materials and part selection; standard documentation practices; P/MMT support for all program design activities by identifying preferred parts; and a multi-program checklist to ensure all parts are evaluated for key characteristics. This approach provides early identification of potential problems such as parts obsolescence, supplier quality, design quality, and producibility. In addition, RMSC predominantly uses CIMS as a design tool which strongly facilitates the use of proactive, standardized design practices within the company. Future plans are to extend CIMS into manufacturing models.

Since centralizing the Components and Materials team, RMSC reduced part level documentation costs by 56% and corresponding cycle times by 20%. The company also achieved a 52% increase in requests for documentation and a 17% increase in requests for laboratory support. Awareness and accessibility were an overall improvement to all RMSC programs.

Composites Integrated Product Team Approach

After the 1993 merger between Hughes (now Raytheon) and General Dynamics, the company decided to move all of its composites expertise to the Tucson facility. A cross-functional Integrated Product Team (IPT) was set up in 1994 to foster composite structure development. RMSC uses this Composites IPT approach to meet its customers' needs for advanced, leading-edge technology at reasonable costs, and often with a rapid development schedule.

Comprised of development and production personnel, the team consists of a key individual for each process technology as well as each weapon systems program that involves composites technology. The composites expertise at RMSC is quite broad, and encompasses compression molding, filament winding, low observables, resin transfer molding, coatings, hand layup, radome bonding, candlering, and metal finishing. This expertise, along with the associated manufacturing capabilities, allow RMSC to determine the best process for fabricating a particular component. By matching the process to a part rather than fitting a part to an available process, the team can create the best quality part at the lowest cost.

Prototyping is largely accomplished on the production floor with manufacturing equipment. This method reduces development cycle time; decreases overhead costs; and increases the accuracy of production fabrication cost estimates. In addition, the risk of scale-up is minimized because fabrication can be proven on the production floor, resulting in a seamless transition to production. Using COTS materials and existing processes/equipment, RMSC developed a hybrid composite structure capable of operating at 2000°F for use in its Lightweight Exo-Atmospheric Projectile (LEAP) and Standard Missile Block IV-A programs. Depending on the actual application, this hybrid structure offers significant cost reductions, as well as performance advantages that are not possible with alternative approaches. Another technology breakthrough is the development of a powder coating process for composites.

RMSC's success with the Composites IPT approach enabled the company to become a leader in low cost, leading-edge composites technology. This approach provides rapid, real-time development; production floor provability; and long term cost savings. The team's achievements include:

- Advanced Medium Range Air-to-Air Missile (AMRAAM) program — 60% cost reduction on target detection device spacers and 36% reduction on target detection device overwrap;
- Tomahawk program — 22% cost reduction on inlet duct;
- Phalanx program — 27% cost reduction on Mass Storage Device Drawer chassis;
- Evolved Sea Sparrow Missile (ESSM) program — one-week prototype development for warhead compatible telemeter radome;
- AIM-9X program — two-week prototype development for harness cover.

Configuration and Data Management

Between 1970 and the early 1990s, Hughes (now Raytheon) tried to adhere to twelve independent Army, Navy, and Air Force standards for its Configuration and Data Management processes. Variation in contracts and obsolete procedures made this task quite difficult. Today, RMSC conducts its Configuration and Data Management system in accordance with the industry standard EIA-649 Configuration and Data Management Process manual.

The EIA-649 Configuration and Data Management Process manual documents the process flow architecture to support industry Integrated Product Development (IPD) teams as well as government requirements, and ensures that government configuration management requirements are aligned to industry processes, tools, and metrics. The manual also provides information for site-wide application of configuration and data management requirements, allowing RMSC to standardize its internal procedures, improve the effectiveness and applicability of personnel training, and maximize the commonality of automated tools for defining, recording, delivering, and accessing information. This approach provides the company with a common set of metrics across all product lines, allowing for evaluations and comparisons across product lines.

RMSC's Configuration and Data Management system encourages program managers to focus on the process, not the rules, and strive for high performance levels. This methodology also helps reveal deficiencies in common processes, so process owners can correct them. The system's ties to measurement tools and metrics enable it to be a fully integrated architecture which enhances electronic data delivery, drawing format commonality, and technical data package preparation.

Cost as an Independent Variable Process

Cost as an Independent Variable (CAIV) is a methodology that recognizes cost requirements as being independent of product performance. RMSC implemented a CAIV process to develop and design military products with the highest quality and performance, at the lowest cost, and in the shortest turnaround time. Prior to 1995, no process existed at RMSC which could provide performance versus cost tradeoffs. In 1995, the Under Secretary of Defense for Acquisition and Technology identified the need to develop a process that could treat cost as an independent variable, and allow the government to procure the most performance for an affordable cost.

The CAIV process is an adaptation of a commercial pricing practice that allows the customer to determine how much performance it can afford. This process reduces cost and risk by setting aggressive and firm cost objectives, increasing competition, incentivizing suppliers, and effectively utilizing producibility programs and design reuse. In addition, the process reduces total ownership, increases customer satisfaction, and provides cost performance that meets or exceeds the customer's needs. RMSC's design teams conduct structural evaluations of various cost-performance tradeoffs by establishing realistic but aggressive cost requirements; devising appropriate metrics; allocating requirements down through the product structure; and managing risk to achieve cost, schedule, and performance objectives. The result is the most cost efficient means of balancing both cost and performance requirements. The customer then determines whether this tradeoff of performance for cost savings is acceptable. Figure 2-1 illustrates the CAIV process map.

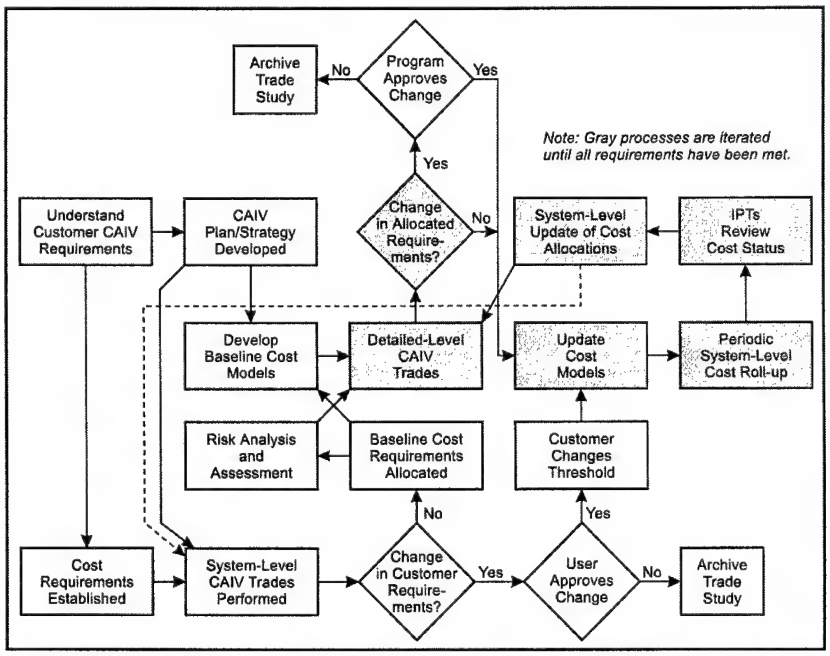


Figure 2-1. Cost as an Independent Variable Process Map

The AIM-9X program is currently in the Engineering and Manufacturing Development phase at RMSC. As one of the Department of Defense's (DOD's) flagship programs, AIM-9X was chosen by the Navy to be a candidate for the CAIV process. After RMSC implemented the process, the program's subassembly recurring unit cost was reduced from $35,000 to $4,000. This represented a savings of $310 million over 18 production lots, while still maintaining product performance.

Design For Environment Program

RMSC developed and implemented a Design For Environment (DFE) program which eliminates hazardous materials and processes, rather than managing the hazardous waste created. This program also enables the company to incorporate alternative materials and processes during the initial program development phases. Prior to DFE, no environmental design alternative guidance processes existed at RMSC, nor were any available from DOD or the Environmental Protection Agency (EPA). Management recognized that hazardous materials and waste were design defects, and changed the company's design philosophy.

DFE is a commonplace dimension in the overall optimization process, creating internal and external (customer/supplier) interfaces that are willing to spearhead green product and production system development. Among the elements for implementing DFE are having a consistent, repeatable methodology or process in place; keeping environmental considerations in mind when designing; performing trade studies and data analysis to determine design alternatives and environmental risks; and assessing the environmental impacts of potential designs.

RMSC's DFE program is fully integrated into the company's Integrated Process Architecture at the strategic systems and detailed levels. Unlike other industry processes, this DFE program does not limit the environmental impact information at the systems engineering level. Instead, design engineers can use individual PC workstations to access this data in addition to approved material parts lists; patented material selector software for material selection; and the Hammer software tool for risk assessment and life cycle analysis when determining a hazard rating of materials. RMSC also provides training for those involved in the design process so they can effectively implement DFE.

RMSC's efforts on the design and implementation aspects of DFE have progressed over the past seven years. DFE alternative and risk data are now part of the company's engineering data structure. Approved material parts lists feature environmentally mitigated or friendly products. More than 1,500 materials have been ranked and over 40 material alternatives offered. RMSC implemented DFE when designing the dorsal fins for the Standard Missile program. The effort resulted in hundreds of dollars in savings per fin, as well as a safer workplace for employees by eliminating hazardous materials.

Design of Experiment Techniques

RMSC enhanced its product design and evaluation process by implementing Design of Experiment (DOE) techniques. These techniques improved the company's efforts by employing a structured approach to organize and evaluate data.

The company uses DOE techniques to evaluate missile performance. Experiments and tests are conducted using Monte Carlo simulations. The DOE process then uses related design parameters, from these experiments and tests, to efficiently identify system variability. The process allows for the efficient identification and elimination of a missile's variability in relation to the test or intended threat parameter. When used accordingly, DOE techniques can optimize quality, decrease development costs, and reduce product development time.

Since implementing DOE techniques, RMSC reduced its computer run times by 88% compared to other methods, and improved the quality of performance measures. The process imparts statistical relevance into resulting indices, and reduces direct labor cost by decreasing the amount of data to be evaluated. Other areas where DOE techniques could work include evaluating and selecting information systems, network systems, and other missile systems.

High Temperature Composite Structures

RMSC developed high temperature composite structures using a graphite substrate and a silicone outer shell. These lightweight composite structures feature a graphite/bismaleimide, load-bearing frame with a non-ablative silicone coating for thermal protection. The hybrid design provides leading-edge technology that is capable of meeting the increased performance requirements of high speed, lightweight missile systems.

Fabricated from COTS materials, this composite structure offers a low cost option. RMSC currently uses this high temperature composite structure for the nosecone for its LEAP weapon system. The alternative was an exotic metal alloy which met the 2000°F operating requirement. However, the alloy's high production costs and heaviness made it an unfavorable choice. RMSC successfully fabricated the complex shaped, varying diameter structure for the LEAP nosecone application by using a filament winding process.

Another application, which RMSC is considering for the composite structure, involves the dorsal fins for the Standard Missile 2 Block IV-A program.

Currently, these fins are being fabricated with a laborious and expensive material system. In its first attempt, RMSC successfully produced a prototype hybrid structure fin. The preliminary cost analysis suggests that the replacement of the current material system with the composite structure will result in a more producible part at approximately 20% of the current cost. With four fins on each missile, RMSC could save approximately $48,000 per missile.

Integrated Flight Simulation

RMSC developed an Integrated Flight Simulation (IFS) which runs performance analysis, requirements verification, design development, pre-flight analysis, and post-flight analysis on simulated missiles. This Six Degrees of Freedom (6DOF), imaging IFS uses detailed models of sensors, target geometry, tracker algorithms, and other simulation requirements to accurately emulate the missile.

RMSC's simulation development process started with the Missile Object-oriented Simulation Tool (MOST), an unclassified generic simulation program written in C++. The company and several of its customers worked together to develop IFS and MOST, and are now well versed in the reusable user interface that drives these simulations. MOST can provide future programs with a mature 6DOF structure for airborne vehicles as well as generic missile models that can be used in trade studies; Monte Carlo simulations; missile phasing capability assessment; and digital model timing control simulations.

Design and validation simulations are a proven, low cost tool which provide users with an alternative to actual tests. RMSC designed the IFS structure to be easily adaptable to changing simulation roles, user needs, and requirements when simulating airborne vehicles that require 6DOF. IFS planning, development, and implementation enabled RMSC to achieve this adaptability in the AIM-9X program.

Plastic Encapsulated Microcircuits and Manufacturers' Part Numbers

RMSC implemented two proactive programs involving plastic encapsulated microcircuits (PEMs) and manufacturers' part numbers. Prior to 1997, the use of PEMs required governmental permission and the creation of an extra drawing which referenced manufacturers' part numbers for ordering purposes. RMSC saw a need to revise these procedures. By placing the manufacturers' part numbers directly on an assembly drawing, the company could eliminate the need to create a non-value added component drawing and reduce costs. In addition, military semiconductor devices make-up less than 0.4% of the total dollar volume in semiconductor areas, and are continuing to decrease. As a result, more military standard parts are becoming unavailable or obsolete, which is increasing the number of PEMs requests to customers.

In 1997, RMSC received contract authorization allowing the company to use PEMs on the AMRAAM program without requiring procurement activity approval. Today, 97% of the available packaged microcircuits are PEMs, which enable the company to avoid expensive redesign costs. These drop-in commercial parts, however, must meet environmental and performance requirements, and cannot compromise a product's mission. If PEM specifications do not meet design criteria, then the part can be tested to determine if it meets all requirements. In addition, state-of-the-art components are now more readily available as commercial devices, and their use will further reduce costs. RMSC is using PEMs in several of the AMRAAM assemblies including the inertial reference unit; VE and AR frequency reference units; infrared receiver; and B filter processor. Commercial databases allow RMSC to verify obsolete parts, recommend alternatives, and receive notification of a part's obsolescence. The company plans to expand the use of PEMs in the AMRAAM program.

Also in 1997, RMSC received governmental permission to place manufacturers' part numbers on AMRAAM assembly drawings. By using this process, RMSC eliminated the use of non-value added component drawings to call out manufacturers' part numbers. Now, the part numbers are placed directly on the assembly drawings. Previously, RMSC spent two to five hours creating, processing, and reviewing AMRAAM component drawings before they could be incorporated into an assembly drawing. By placing the manufacturers' part numbers directly on an assembly drawing, the company incurs no drawing costs. The manufacturers' part numbers are also the common denominator between the unique drawing and the specification systems, which were established by each Raytheon division. This process has the added benefit of reducing costs while not compromising configuration management.

RMSC's use of PEMs brings the company lower costs, greater selection, and better availability compared to military devices and, in some cases, higher quality and reliability. Obsolete or unavailable military standard parts usually have a commercial-grade PEM replacement which is readily available. RMSC replaced a

$150 military standard amplifier on AMRAAM with a commercial PEM at a cost of $3.50. In addition to individual component savings, the redesign of existing hardware is minimized by using PEMS.

Pumping Very Low Water Yield Wells with Conventional Submersible Pumps

RMSC builds water wells in tight, low permeability clay units as part of a pump-and-treat redemption system for a zone of contaminated shallow groundwater. Conventional 0.5-horsepower, 480-volt submersible pumps are the most cost-effective devices to use in these areas, but draw at ten gallons per minute (gpm), which rapidly deplete the well's water. As a result, the pumps burn out when operated under this no-load condition. Although very low yield pumps are available, they are expensive and not as reliable as submersible pumps. Their associated submersible controllers with downhole probes are also unreliable and require high maintenance.

RMSC resolved this problem by installing electrical load-sensing motor controllers on 41 of its low water yield redemption wells. When a no-load current condition is detected, the controller turns the pump off for a pre-designated period of time. This above ground device cycles the pump on and off according to the flow of groundwater into the well. As a result, the company can use conventional submersible pumps to draw low yield (0.1 gpm continuous flow) water wells. The controller also measures the amperage of the pump's motor in addition to other operating parameters. When a well pumps dry, the load on the motor drops and the amperage decreases accordingly. The controller senses this decrease and shuts off the motor. After a pre-programmed time, the controller restarts the well. The pre-programmed time is determined by measuring the amount of time it takes for the well casing to refill with groundwater.

The motor controllers enable RMSC to use its existing, readily available, low cost submersible pumps in very low water yield wells. The controllers cost $170 each compared to the $500-a-piece replacement cost for existing submersible pumps. Alternatively, retrofitting submersible pumps with low rate bladder pumps or centrifugal pumps with controllers would cost between $1,000 and $2,000, and these devices are not designed for continuous use. RMSC's motor controllers have been in operation for more than a year, and are quite reliable. The company has also realized significant savings from cost avoidance.

Quality Function Deployment Program

RMSC implemented its Quality Function Deployment (QFD) program as a structured process for gathering information and comprehending the voice of the customer. The program ensures that those aspects of a requested product or service, which the customer deems most important, will be given special attention. By using QFD, RMSC can align and optimize designs, materials, and processes to satisfy the customer's expectations.

QFD is a flexible, robust tool used in all phases of a product/process from concept to production. The program identifies and prioritizes high leverage activities which directly relate to customer satisfaction. RMSC applied QFD to cost reduction initiatives, trade studies, test equipment design, reliability improvement, finance process improvement, and information technology strategic planning. As a result, the company has met or exceeded customer expectations. QFD provides the user with a systematic and structured process for translating the voice of the customer into corresponding requirements and actions. This process allows the user to deploy quality, reliability, cost, and technology throughout all phases of product development. QFD uses a House of Quality format which stores the data used to document the process. RMSC management supports the QFD program, and gave its approval of QFD training from the American Supplier Institute in 1988. Customer involvement and representation made QFD successful at RMSC.

The QFD program identifies and defines vague requirements; promotes a team approach; increases organizational ownership; and reduces cycle time and engineering changes. Since using the QFD program, RMSC has avoided high cost of quality, prevented costly engineering changes, fully comprehended customer requirements; and prioritized activities. The most important benefit of QFD is that it helps the user to truly understand the voice of the customer. RMSC also extended its QFD program beyond its defense sector work to the community. The company helped the state of Arizona apply QFD techniques to its welfare reform and healthcare initiatives.

Rapid Prototyping

RMSC implemented a rapid prototyping method to fabricate models directly from 3-D CAD data. This method provides a quick physical visualization of hardware concepts without the need for expensive and time-consuming machining, tooling or drawing generation. Rapid prototyping can produce a prototype

overnight with higher accuracy than previous methods could accomplish in weeks.

Through the use of incentives, RMSC is promoting rapid prototyping tools and good design practices. The stereolithography apparatus is available to all programs via the Knowledge Center Southwest. In addition, the company will pay for unlimited design prototypes to encourage the use of these tools. This approach has converted a virtually unused asset into such a popular tool that RMSC is planning on acquiring a second one. Rapid prototyping supports RMSC's tenets for successful operations including structured methodology; common tools and processes; agile creative environment to promote learning; and rapid learning as part of reduced cycle time. Other types of prototypes (e.g., selective layer sintering, laminate object manufacturing, fused deposition modeling) are outsourced by RMSC.

Some examples of rapid prototyping's effectiveness include:

- Tomahawk program — The original Tomahawk tailcone was a 22-inch diameter by 3-foot length assembly with more than 75 parts and 800 hand-placed rivets. Desiring a single piece casting, RMSC used its 3-D solids model in CAD to produce rapid prototypes and fit test them around an engine to verify the design. The Pro/Engineer model was then sent to the casting supplier, who worked with RMSC to create the part and tooling from the model. Rapid prototyping produced a more accurate tailcone which is four pounds lighter, and can be cast in one piece.
- Radio frequency wave guide — As a complex part with tight tolerances, the radio frequency wave guide was prototyped in a polymer model. Designers were able to plate the prototype, and can use the part as-is in their environment. Not all operational environments would permit such a use but, where feasible, this process constitutes substantial savings.
- AIM-9X program — Designers used rapid prototyping to fit check the AIM-9X control actuation system assembly. The results showed that this component needed to be cast since it was impossible to machine as planned. By identifying this potential problem early in the program, RMSC avoided substantial costs and problems.

Designers use accurate, rapid prototyping methods to perform fit and function tests early in the process, generate more iterations and alternatives, and receive prompt feedback. This approach optimizes designs and avoids substantial costs later in the process. Rapid prototyping also reduces manufacturing costs by creating more producible designs, encourages design-for-manufacturing assembly, and constructs master patterns for vacuum forms, castings, and tooling. Other benefits include improved IPT communications; reduced design and manufacturing times; and better comprehension and response capability regarding requests.

Raytheon Electronics Packaging Consortium

RMSC developed a collaborative organization to leverage the broad range of electronic packaging resources available across the Raytheon corporation. Previously, each Raytheon division relied on its in-house staff for engineering knowledge. Pressures on available discretionary funds hindered internal development of all the packaging technologies required by RMSC product lines. With the establishment of the Raytheon Electronics Packaging Consortium (REPC), the corporation can draw from a larger technical engineering resource to achieve competitive designs and cost savings.

REPC consists of representatives and senior executives from Raytheon business units. All electronic packaging and new business investment projects within RMSC are grouped and managed under the REPC umbrella. REPC's guiding principles consist of customer satisfaction, competitiveness, quality/reliability, and product enabler. The consortium's functions include identifying current packaging capabilities; communicating packaging capabilities and key technologies throughout the corporation; facilitating roadmap development; providing a means for information exchange among Raytheon Centers of Excellence and Engineering; and linking packaging investments to strategic systems goals.

REPC enables RMSC to gain access to projects in other Raytheon business units via direct sharing, workshops, and technical reviews. Shared membership costs in external consortia allow RMSC to participate in commercial surface mount infrastructure development, and to continuously view commercial packaging trends and roadmaps. This approach has been extremely useful in validating the corporation's technical plans. REPC also provides RMSC with a 10:1 leverage, returning $10 in resources for every $1 invested. RMSC's consortium model can be applied to any technology development function or organizational structure which must work across business segments, business units, or programs.

Six Degrees of Freedom Simulation Development Process

RMSC built a Six Degrees of Freedom (6DOF) model that simulates the prelaunch and flight operations of a missile, including atmospheric conditions and global positioning/satellite communication systems. The 6DOF model accomplishes this feat by using mathematical computer representations of missile subsystems; mass property databases; simulations of atmospheric conditions; global positioning/satellite communication systems information; and other missile flight hardware and software. RMSC has simulated various missile subsystems by creating inertial sensor, propulsion, actuator, and non-linear aero/hydro models. These subsystems handle missile guidance, navigation, control, and flight performance.

RMSC accomplishes 6DOF simulations by developing two modeling categories. The first is by creating all software non-real-time simulations for statistical analysis of navigation system and flight performance (e.g., covariance analysis, Monte Carlo simulations). The second is by using real-time, hardware-in-the-loop simulations complete with sensor representation and flight visualization capabilities. In the early stages of development, RMSC implements a progressive configuration control practice to facilitate creativity in a less-structured environment. As the simulation model matures, the company switches to a more formal configuration control for hardware and software.

RMSC's software development work led to the Software Engineering Practices and Procedures (SEPP) for simulation software development, which uses ISO-12207 (Software Life Cycle Processes) as a guide for best commercial practice. SEPP identifies and defines various software development items such as project management organization, responsibilities, resources, and metrics; software development process and associated milestones; software engineering environment and programming standards/practices; and software configuration management and software quality assurance policies and practices.

Using the software development items along with contract requirements allow RMSC to yield a controlled software development process with predictable, manageable results. Although it currently measures the effectiveness of software development improvements in qualitative terms, RMSC noted benefits in other areas: software build/version control; completeness of problem assessment and corrective action implementations; common models for use by hardware and software simulations where possible; and internal and external task coordinations.

Verification and Validation of Simulation Models

RMSC developed a process that expedites software development by using the same software for modeling, algorithm development, simulation performance analysis, and flight software code development. The company also designed a process which uses a common model to validate software development, integration, and testing.

While developing flight software, RMSC discovered that most errors occur during the writing phase and typically create three problems: (1) failure to adequately verify the algorithms under realistic flight and operating conditions; (2) the hardware designer incorrectly communicates the defining algorithms to the software designer; and (3) failure to thoroughly test the software code at the unit, component, or configuration item levels. RMSC also noted that flight test performance predictions and post-flight performance analysis require a validation tool. Since flight tests are costly, the company strives to minimize the required number of tests and maximize the probability of success.

By developing algorithms in an accurate simulation and using the code directly in the flight software, RMSC prevented most errors from being incorporated into the software. This effort provided early identification of software failures, which significantly reduced costs associated with locating and correcting code errors later in the development process. RMSC also involves the analyst in the flight code development, which improves performance by addressing critical issues during the development of the in-real-time flight software. As a result, the company resolved many critical issues early in the development phase including data synchronization, throughput margins, data resolution, and interaction with other computer software units.

These software development guidelines enable RMSC to maximize the verification and validation of simulated models while reducing the number of tests required for performance evaluation. By following this approach, the company reduced the overall cost of code formulation, verification and validation, and final testing.

WarGaming Laboratory

RMSC developed the WarGaming Laboratory which allows users to simulate products against an intended threat on a digital battlefield. RMSC, as well as government agencies, use this laboratory to develop

simulations which model air combat engagements, battle group air defense, strike/air defense, and other missile engagement and defensive scenarios.

The WarGaming Laboratory is supported by a network of Silicon Graphics, SUN and VME workstations that host the simulation models and graphical output software. These workstations process the analytical- and physical-based computer models that simulate threat characteristics, weapon characteristics, flight profiles, environmental constraints, and other combat simulation requirements. Users animate their scenarios by viewing a synthetic battlefield simulation projected on a large screen. These simulations provide valuable insight, so missiles can be properly designed to counter intended threats.

RMSC uses the WarGaming Laboratory's simulations to predict weapon systems performance and operational effectiveness of its products in a combat environment. The simulations help the company prepare top-level weapon system requirements in relationship to operational concepts; missile lethality and effectiveness; airframe capabilities and constraints; cost; and other engineering design parameters. Currently, RMSC is integrating the product development process by evaluating product simulations for actual hardware manufacturing.

Production

Automated Calibration System

RMSC instituted the Automated Calibration System (ACS) to maintain calibrations on a broad spectrum of equipment. This computer-controlled, interactive system provides high quality, consistent results for calibrating engineering and production test equipment found in automated test equipment stations.

ACS was developed to improve productivity by automating the calibration process of direct current, low frequency, radio frequency, and microwave test equipment. However, the system also provided additional benefits through easy use and maintenance of calibration operations, uniformity of system operations, software designs, and calibration procedures. With the ability to decrease calibration turnaround time, ACS can handle future workload increases by reducing schedule interruptions, lowering program costs, and eliminating manual interference or misinterpretation of equipment manual requirements.

ACS eliminated the need for highly experienced metrology technicians; long lead time scheduling of equipment calibrations into production cycles; and recurring costs associated with software development. This calibration system also provides a cost effective method of meeting calibration requirements as workloads increase.

Compliance Management Report Card

RMSC's Environmental, Health, and Safety (EH&S) Compliance Management Report Card was created after Hughes (now Raytheon) merged with General Dynamics in 1993. The EH&S department initiated this environmental compliance management system to track multiple facilities and programs. The Report Card continues to be a valuable tool for RMSC in handling the merger of programs and facilities.

The Compliance Management Report Card uses a color-coded array of symbols (e.g., stars, squares, octagons) to identify each facility's level of compliance (Figure 2-2). The symbols indicate the percentage of closed audit findings in various categories, while the color notes the alert status. Yellow identifies a caution for a facility, resulting in force action. Arrows which accompany symbols reflect whether progress is being made on audit findings. The colored symbols provide an easy visual guide, so employees and management

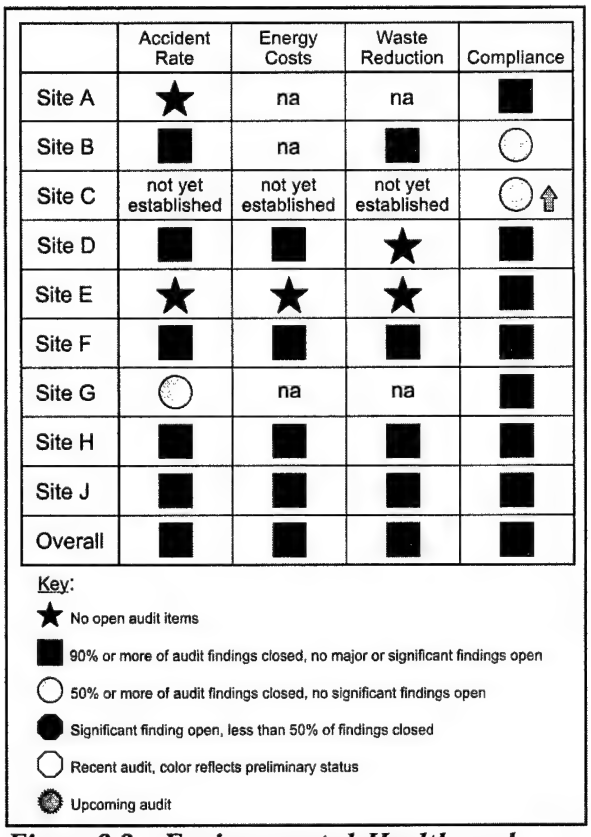


Figure 2-2. Environmental, Health, and Safety Goals Status

can quickly determine a facility's standings. In addition, each Report Card is accompanied with documentation for the 29 EH&S programs being evaluated.

The EH&S Compliance Management Report Card provides RMSC with a quick and easy way to identify successes and potential problems at each facility. This environmental compliance management system assists RMSC with its leadership plans for efficiently improving performance.

Depot Parts Marking and Identification

One of RMSC's services is depot-level repairs of military defense system parts, assemblies, and subassemblies. The marking requirements for identifying remanufactured, repaired, and modified parts and assemblies are often specified in the federal government's Technical Data Package (TDP). Typically, these requirements call for etching; epoxy ink and rubber stamps; stenciling; inked plastic tags; hot stamped insulation; or marked heat-shrink tubing. Many of these techniques are labor intensive for the small quantities associated with depot-level repairs, and usually generate hazardous waste materials.

RMSC launched a Single Process Initiative (SPI) to investigate alternative marking capabilities and methods, and to obtain customer concurrence for using improved and more cost-effective methods. After analyzing alternative marking methods, the SPI team proved that many of the TDP marking requirements could be satisfied with COTS marking systems. These COTS systems are relatively inexpensive and do not generate hazardous waste. RMSC now marks its repaired items by using imprinted polyamide labels for flat or slightly cylindrical parts, and imprinted commercial, heat shrinkable labels or wraparound, self-laminating labels for wires, cables and harnesses. The company has received concurrence from DOD customers to use these methods for marking depot-level repaired parts.

RMSC's technique for marking parts and equipment offers many benefits and is easily adaptable to any size organization. The technique reduces marking application time, lowers costs, increases productivity, and meets the part identification requirements of TDP. In addition, this method supports the practice of implementing commercial processes which meet military specifications. RMSC estimates that its first-year cost savings is in excess of $20,000.

Distributed Receiving and Supermarkets

Distributed receiving and supermarkets are key factors to achieving production agility. RMSC's seven-phase systemic approach promotes continuous improvement through the elimination of waste. This approach uses agile manufacturing processes to deliver parts directly to the production lines on an as-needed basis. Prior to 1995, RMSC housed and inspected all purchased parts in a central receiving area located 14 miles from the production facilities. The parts remained there until the individual production areas requisitioned them. Over the years, the increased usage of certified vendors and source inspections has decreased the need for a central inspection area. Four years ago, RMSC began decentralizing its receiving process by setting up individual storage locations (supermarkets) in the production areas.

Parts that do not require a receiving inspection are shipped directly to these supermarkets from the vendor. This approach enables RMSC to store parts as close as possible to the manufacturing process which uses them. By setting up the supermarkets in existing production space, the company freed up 26,000 square feet of storage space in its original receiving area. The first production area to change to the supermarket concept was the Tomahawk missile line. Since then, five of the manufacturing factories and eight of the production areas have been converted. In some cases, the company established receiving hubs to serve smaller parts storage areas or minimarts. Today, 50% of RMSC's production materials are delivered directly from the vendor to these hubs and supermarkets. By increasing the availability of parts at the production area, the company reduced total planned cycle times by up to five days, and decreased actual receiving processing time by more than a day.

Since implementing these processes, RMSC eliminated unnecessary transportation and repackaging costs, and reduced the receiving-to-floor cycle times from one to five days for various production lines. In addition, production teams can directly control the response time for parts and kits to the production site. RMSC continues to set up additional supermarkets as other missile production lines are switched over to agile manufacturing methods.

Electro-Optic Sensors and Precision Assembly Multi-Sensor Factory

RMSC integrated the electro-optic sensors and precision assembly (EOSPA) area into a common manufacturing factory that produces sensors for various missile programs. By using a central manufacturing site, the company can easily meet changing requirements and configurations without rearranging production areas.

In 1997, RMSC reorganized this factory by setting up flexible work cells dedicated to building specific product types in standardized operations. These work cells increased the use of existing capital equipment, and maximized the workforce knowledge base across all EOSPA product lines (e.g., spinning mass gyros, stabilized platforms, active optical target detectors/fuses).

The consolidation of the EOSPA workload is in response to the company's changing work environment. The EOSPA workload has transformed from a high volume, low mixture atmosphere to a low volume, high mixture setting. The EOSPA Multi-Sensor factory has produced many benefits for RMSC:

- Work-in-process reduced by 52%
- Work-in-process to sales ratio improved by 82%
- Factory square footage reduced by 42%
- Manufacturing cycle time improved by 79%
- Pilot area square footage reduced by 25%
- Pilot area cycle time improved by 92%
- Schedule performance improved by 91%
- Facilities cost avoidance saved $2.5 million
- Part numbers reduced by 11% (Stinger and Rolling Airframe Missile programs)
- Pilot area schedule performance improved by 100%

Since implementing the EOSPA Multi-Sensor factory, RMSC has reduced its product and support costs. This approach also makes the company flexible and competitive for emerging product programs.

Flexible Work Cells

Before RMSC could implement agile manufacturing concepts into its Standard Missile program, the company needed to make major changes to a factory floor that had been designed around a rigid, linear flow storage and retrieval system. Starting with a proven overhead utility grid design, the Standard Missile Agile Implementation Team developed and set up flexible work cells. These work cells provide RMSC with rapid response and reconfiguration capabilities to meet changing requirements with minimal disruption to production. All workstations within a cell are mobile which promotes a small lot production strategy, and improves production flow across multiple product types. The use of these work cells also improves communications between IPT members, and provides immediate problem-solving responses.

By redesigning the area for the Standard Missile program, RMSC freed up more than 15,000 square feet of valuable factory floor space, and positioned three additional production programs into this area. Flexible work cells enabled the company to consolidate the entire missile assembly at Tucson. Three major subassemblies and all of the guidance section activities, previously produced in separate locations, were incorporated together by RMSC.

The implementation of flexible work cells allowed RMSC to change its Standard Missile program from an outdated, rigid linear line flow process to one that meets today's needs and has the flexibility to meet the changes and challenges of tomorrow. The company can modify the production work areas, as necessary, to facilitate a more efficient workflow as product types change. With these improvements, RMSC can rapidly respond to and meet its global customers' changing needs.

Hybrid Microelectronic Assembly

Based on performance specification MIL-PRF-38534, RMSC developed the common process document, D-102, for the production of hybrid microelectronic assemblies (HMAs). This document enabled the company to standardize and improve its HMA production efforts by employing contractor self-governance, continuous process improvement, and team-based decision making.

Previously, the variations in specifications, standards, screening, tests, inspections, and procedures resulted in an array of processes which led to costly training and numerous errors. By standardizing the process, RMSC maximized product quality while minimizing the costs. Self-governance encouraged the entire RMSC team, including customers, to participate in the cooperative development of processes to produce more efficient HMA manufacturing. Emphasis was placed on reducing the following: manufacturing cycle times; testing and screening levels; and defects at the earliest stage of the manufacturing process. Process controls were made to pursue best-cost reduction decisions, while staying focused on cycle time reduction and quality improvement. The company measured a wide range of data to identify the value-added changes.

Since implementing this effort in June 1996, RMSC significantly reduced its cycle times by 50% (Figure 2-3). Process results are monitored electronically and are available to team personnel, management, and customers. Not only has the team clearly accepted ownership of their process, but cross-functional team

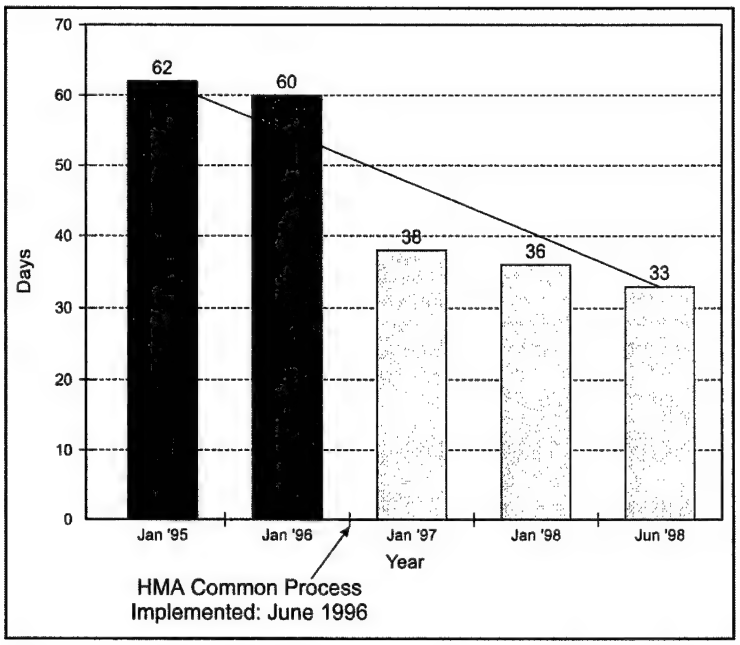


Figure 2-3. Hybrid Microelectronic Assembly Cycle Time

improvement efforts continue to be implemented. Nearly $1 million in annual cost savings has already been identified by the company. Efforts are currently underway to migrate the process throughout all of RMSC.

Integrated Product Team

In 1966, Hughes (now Raytheon) established an Integrated Product Team (IPT) for U.S. Air Force Plant 44 (AFP44). IPT works as a comprehensive project management/communications tool among organizations, including the Air Force, EPA, Arizona Department of Environmental Quality, and RMSC. This tool is uniquely applied to environmental programs and projects, and sets up a teamed organizational structure with representatives from each organization who handle specific areas of concern.

Prior to IPTs, communications between RMSC and the Air Force were disorganized which often resulted in duplications, delays, and cost over-runs. RMSC recognized the need to streamline and simplify its method of communication, and reorganized its team to resemble the Air Force's method. Two groups were established: the IPT, consisting of coordinating management, facilities, compliance, pollution prevention (P2), restoration, contracting, and program/financial management; and the IPT Support, consisting of safety, health and environmental affairs, explosive safety, legal, public affairs, security, and fire protection.

Joint meetings or teleconferences are held quarterly, while the RMSC IPT meets monthly. This approach significantly enhanced communications, and streamlined the coordination of government funded projects between the two remotely located organizations. RMSC also reduced approval responses for the Air Force project from six months to one month. Change in scope processes, which typically took nine to 18 months, can now be completed in about three months.

Lay a Missile on the Table

RMSC developed the Lay a Missile on the Table (LAMOTT) process for the rapid development of a functional missile, prior to the Engineering and Manufacturing Development phase of the DOD acquisition process. The goal was to make a first missile with a functional guidance system in less than a year. This would produce a 300% decrease in development cycle time for this type of product technology and design maturity.

In the course of its successful effort, RMSC demonstrated its plan to convert to an agile manufacturing strategy by employing such practices as the General Motors Powertrain Group's methodology and training, material flow through a certified supplier chain, parts delivery directly to the area of use, and supplier process control. The company also displayed cost credibility through the use of actual factory processes (versus conventional prototyping shop) in building three missiles and verifying producibility assumptions. Methods for achieving cost reduction, a driving factor in the government's Request for Proposal, were done through many methods such as using inexpensive components (e.g., PEMs); simplifying mechanical designs; performing process designs for best commercial practice/standards; and implementing a flowdown of acquisition reform concepts to suppliers.

By using LAMOTT, RMSC demonstrated the maturity of its technology and process methodologies in its proposal for the AIM-9X missile. This technique offers users the potential to gain detailed design and manufacturing information much earlier than with conventional methods, and provides an opportunity to accelerate/reduce the Engineering and Manufacturing Development schedule. LAMOTT also provides earlier credible cost proposal data and design-to-cost predictions; helps early identification and mitigation; and allows suppliers to be involved in the design process.

Manufacturing Simulation

RMSC has been involved with manufacturing simulation for more than twelve years. During the last two years, the company has taken this computer tool to a new level by using a windows-based software called ProModel. This tool visually animates a computer model which helps users identify schedule risks, facility allocations, and cost impacts associated with making changes within their organization. ProModel provides the best analysis of expected results by animating the movement of forecasted/actual data or planned processes. Advanced planning of these changes helps to ensure a program's success prior to changing a complex manufacturing system. The tool can also predict the outcome of a simulation throughout the life of a program.

Customer satisfaction is the primary objective of ProModel. RMSC used this manufacturing simulation tool to start up the Navy's Rolling Airframe Missile (RAM) Launcher International program. As a result, the RAM program was completed on cost and two months ahead of schedule. Another start-up involved the Army's Tube-launched, Optically-tracked, Wire-guided (TOW) 2A retrofit program. Over the two-year lifespan of TOW 2A, the company met all schedule and cost goals.

RMSC continues to foster manufacturing simulation within the company as well as throughout the DOD community. Since implementing ProModel, RMSC has been able to minimize tooling and facility risks; ensure program schedules are met; and respond to customers' concerns and questions.

Methylenedianiline Composite Replacement

As composite technology's popularity and acceptance in military applications increased, more researchers began looking into the health and safety factors of composite materials in regard to the workforce. Methylenedianiline (MDA), a suspected carcinogen, turned out to be one of the riskiest materials. Previously used in four of its products, RMSC has now eliminated MDA composite material from its manufacturing processes. The use of MDA had required RMSC operators to wear personal protective clothing (e.g., Tyvek body suits, special gloves); take showers during breaks, lunch, and at the end of the day; and be subjected to routine medical tests.

Although no regulatory agency pushed for the elimination of MDA, RMSC wanted to remove this potential health risk from its workers. Several alternative technologies were available on the open market, but few provided the temperature and working pressure data needed to consider them as MDA substitutes for missiles. Senior leadership at RMSC directed the change to take place anyway, but doubted the possibility of savings. Teams were assembled to investigate and test multiple composite products for feasibility. Among the factors to be considered were the unique characteristics of the Standard Missile's dorsal fin and the AMRAAM's spacer, absorber pad, and harness cover.

The MDA replacement process took three years to complete, and provided RMSC with several unexpected benefits. Among these were minimal modifications for tooling; a significant increase in cycle times; and the elimination of personal protective clothing, showers, and routine medical tests. In addition, the company realized an overall production savings in excess of $200,000 annually. RMSC's approach to the MDA situation shows that benefits can be realized through self-imposed changes prior to the involvement of regulatory agencies.

Nitric Acid Recycling Program

Nitric acid is typically used in such processes as the finishing of aluminum and stainless steel alloys; the stripping of nickel fixtures; and the plating of copper, tin, and lead. However, nitric acid is also a reportable chemical on the Superfund Amendments and Reauthorization Act, Title III under Section 313 regulations, and is targeted for reduction or elimination. In addition, the Air Force enacted a P2 initiative which called for a 50% reduction in nitric acid usage.

To comply with these directives, RMSC established a Nitric Acid Recycling program. The program's scope called for the procurement and installation of four purification units so that metallic contaminants could be removed from nitric acid solutions allowing indefinite reuse. RMSC investigated applicable technologies for recycling nitric acid, and identified diffusion dialysis and resin sorption as two possible methods.

Diffusion dialysis technology uses an anionic exchange membrane that contains positively-charged groups on a polymer matrix surface. Anions (e.g., nitrates) can pass through the membrane, but most metal cations cannot. This method allows nitric acid to diffuse through the membrane into a freshwater stream and return to the process tank, while positively-charged metal ions are blocked and remain in a low acid concentration waste solution. The second technology,

resin sorption technology, relies on sorption and desorption. During the sorption step, nitric acid from the working solution passes upward through a tightly packed resin bed. Free acid is then sorbed by the resin, while the metal salt solution passes through as waste. During the desorption step, water passes downward through the resin bed to desorb the free acid from the resin, and move it back into the working solution.

RMSC chose the resin sorption technology (Figure 2-4) because this method was simpler, required fewer pumps, and cost less to maintain. The four resin sorption units cost approximately $20,000 each, and have a payback time of two years. RMSC's Nitric Acid Recycling program has been a good environmental and business investment. The company can recover 95% of the acid used to process its components. By recycling the spent nitric acid, the company also significantly improved the process control, and reduced labor time, raw chemical purchases, hazardous waste sludge, and waste treatment costs.

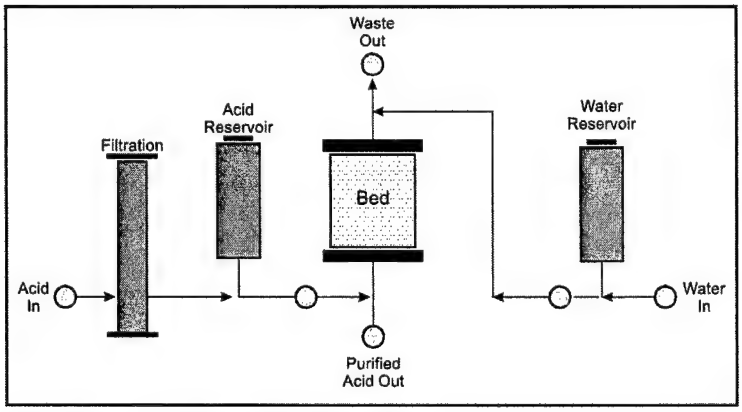


Figure 2-4. Nitric Acid Recycling

Powder Painting of Non-Conductive, Composite Materials

Powder painting or coating needs to be applied to a conductive surface to be successful. Typically, the statically-charged powder paint particles will be attracted to and adhere to a grounded, metal part. The part is then cured in an oven to form a permanent paint layer. Cure times must be short enough to cure the paint layer without damaging it, but long enough to allow volatile organic contaminants (VOCs) to escape from the paint. RMSC has expanded this technique by developing a way to apply powder paint to non-conductive, composite materials.

RMSC uses an anti-stat to create a conductive layer on a non-conductive surface. Commonly used anti-stat products include household sprays that remove static from clothing or a computer monitor. After experimenting with water-based, COTS, and other anti-stat/paint materials, RMSC identified a COTS static guard in combination with an epoxy Herberts paint as being the most effective under a wide range of requirements. The Standard Missile program's dorsal fin, composed of graphite/bismaleimide, was the first component to be painted by using this process. All painted surfaces were then subjected to military specification environmental tests (including salt fog, fluid exposure, and flexibility), and passed.

RMSC's process for powder painting non-conductive, composite materials has reduced hazardous exposures and wastes; streamlined process steps; decreased cycle times; and produced cost savings. Preliminary estimates based on several prototype dorsal fins indicate a 60% cost savings with the powder paint method compared to wet methods for non-conductive surfaces.

Pressurized Recharge Wells

Technology has improved since RMSC implemented the Installation Restoration program at AFP44. To obtain the best performance out of its existing equipment, the company developed several cutting-edge cleanup practices for recharge wells. Two such improvements are re-engineering the well heads to inject pressure into the wells, and removing some of the control mechanisms at AFP44.

RMSC's recharge wells were originally constructed with computer-actuated valves which controlled the flow of water into the wells. The computer received information on the well's water level via a pressure transducer, and then opened or closed the valve to maintain the water level at 15 feet below ground surface. However, various situations can interfere with this process. Since water flows in under the force of gravity, a computer or valve malfunction can cause a well to overflow water onto the ground. A well can also lose its recharge capacity due to the clogging effects of calcium carbonate, so every year, RMSC had to redevelop its wells at a cost of $1,800 a piece. Prior to the injection step, the water at AFP44 was pH-adjusted with sulfuric acid and filtered through sand filters. RMSC theorized that the calcium carbonate was precipitated in the well as the water fell in the injection tubing. The precipitation occurred because the water would be under vacuum as it fell and carbon dioxide would be lost, thus

changing the carbonate balance. To counteract this effect, the company converted the wells so they could be injected under pressure. This process involved redeveloping the wells one more time; removing the level sensors and computer-controlled valves; sealing the well heads; and adding air relief valves to the casings. With these changes, the water is now delivered under pressure to the wells from computer-controlled pumps at the treatment plant. Since converting the wells in 1991, RMSC has not needed to redevelop a single well, and has experienced only a small drop in recharge capacity at each well.

The pump and treat groundwater remediation system at RMSC also uses pressurized recharge wells to return treated groundwater to the aquifer along the margins of the contaminant plume. The remediation system is designed to treat groundwater contaminated with trichloroethylene (TCE) and 1,1-dichloroethylene (DCE) which is pumped from a two-square mile plume. The system operates at 3,000 gpm, and must reinject this water continuously into ten recharge wells. Most recharge wells are 180 to 200 feet in depth and have a water table at 90 to 120 feet below the surface. The wells are gravel packed and constructed with well screens that have openings of 0.08 to 0.125 inch. Injection pipes for the wells use either a three- or four-inch diameter, and extend below the water table. Water is injected into the wells under pressure, with a maximum of 15 pounds per square inch as measured at the well head. The wells are equipped with air relief valves at the top of the casings, allowing air to flow in and out of the top of the well, but preventing water from flowing out. The valve performs two functions: (1) lets air out when the well is turned on, allowing the water level to rise in the casing, and (2) lets air in which breaks the vacuum when the well is turned off, allowing the water level to fall in the casing.

These modifications have enabled RMSC to save $1,800 per well every year since 1991. By removing the computer-actuated valves and level sensors, the company eliminated surface spills, and simplified its maintenance and operation. RMSC's injection well modifications could produce similar benefits in other injection well situations, if the water to be reinjected contains enough calcium carbonate to cause precipitation problems, and if the water has been filtered and pH-adjusted below 8.0. Under these conditions, pressurized recharge will maximize the sustained recharge rate into a well and minimize the need for well redevelopment.

Procurement and Production Processes, Tools, and Metrics

RMSC uses simple visual tools in its RAM MK 49 launcher and Phalanx Block 1 system integration areas to schedule production, track procurement, provide predictive metrics, and help management control the overall system build. These tools provide visibility to critical processes that were not manageable previously. The former method involved retrieving a very lengthy data report from Manufacturing Resource Planning (MRP). Personnel spent hours searching this cumbersome report to find critical information such as purchase requisition release, order placement, and part receipt.

The RAM and Phalanx weapon systems are considered low volume, high part mix programs. Only one to two systems are produced per month, but each has a product mix of more than 10,000 parts, covering a broad range of technologies. The work primarily consists of assembly; system test and checkout; subcontractor oversight; fleet repair; spare part provisioning; paint; and shipping. Part obsolescence, gaps in the production build schedules, and cost pressures add to the difficulty of keeping these systems' production processes and parts delivery on schedule.

The visual tools consist of procurement, production, and management tool reports that are easily generated from MRP each week. The procurement tool report provides a checklist for IPT members, and lists all information on purchase requests, purchase orders, and receipt/need-to-complete dates. The production tool report also provides a checklist for IPT members plus work cells from which priority tasking can be accomplished. The management tool report is used in weekly team leader meetings. This report displays all major items for weapons build, and provides visual guides such as shading to reflect completion dates; flags to show past due dates; and color codes to indicate the responsible IPT. Metrics are established throughout all the reporting tools, enabling the company to determine a system's status and performance.

By using procurement, production, and management tool reports, RMSC can effectively document and manage the production and tracking challenges of low volume, high part mix systems. Standard processes enable the company to clearly convey personal roles of responsibility and rules of engagement. Since implementing these visual tools, RMSC improved supplier performance and significantly reduced shortages; established a stable production schedule

that almost eliminated emergency shift changes; achieved 24 months of on-time spares delivery; and completed the RAM and Phalanx weapon systems two months ahead of schedule.

Production Integrated Product Teams

Procurement quantity reductions resulted in a decrease of support staff on RMSC's RAM and Phalanx weapon system programs. Since both programs involved very high part counts as well as complex and hard-to-procure items, a change from the traditional organization structure was required to manage the programs. This realization became apparent between 1993 and 1995 when significant and continual manufacturing issues (e.g., cost overruns, missed completion schedules) caused customer satisfaction and confidence to slip. The company overcame these challenges by applying an Integrated Product Team (IPT) structure to the RAM and Phalanx programs.

January 1996 marked the start up of a new weapon systems contract and the change of these programs' organizational structure. RMSC established the IPT structure by combining the RAM and Phalanx support staffs, and then subdividing the structure into seven IPTs. Five of these teams were responsible for buying and building the products. They were chartered with cradle-to-grave stewardship for the products assigned to their team, such as design, proposal, procurement, production, and post delivery support to the customer. The two remaining teams managed the administrative processes by ensuring minimal handoffs across functions or teams, handling the managerial duties of operating systems, and overseeing spare parts contracting.

RMSC changed the organizational structures of its RAM and Phalanx programs by breaking down their functional units, getting the customer involved, and setting up empowered IPTs with a common goal. This approach led to open and frank relationships with customers, a quicker response time in addressing problems and implementing solutions, and an ahead of schedule delivery of finished products. Since establishing the IPT structure, RMSC reduced the RAM and Phalanx programs' cycle times by 50% and the factory floor space requirements by 30%. Both programs can accomplish more work with fewer people by using cross-functional teams with a set of visible objectives. Employee morale has significantly improved, and customer's confidence and satisfaction have been restored.

Production Plan Review

RMSC's Integrated Process Architecture is designed to leverage programs (via common processes) by aligning enterprise goals; providing structured approaches for planning and executing programs; and achieving continuous measurable improvement in performance. One such process that meets these objectives is the monthly Production Plan Review (PPR) chaired by a program's master scheduler. Prior practices at RMSC did not produce the level of communications needed to address production schedules in a proactive manner, and avoided front-loaded schedules that operated in a past-due environment.

PPR relies on cross-functional participation by process owners, including procurement, program office, business office, production control, and master scheduling. The process enables the company to examine production-build plans and schedules in detail, and review key enterprise metrics for avenues of improvement. By using internal material audits and controls, PPR ensures consistency across all programs, and compliance with DOD's Material Management Accounting Standards. Color-coded scheduling performance metrics are used to establish guidelines for rescheduling: blue is on schedule; green is four weeks or less behind; yellow is five to eight weeks behind; and red is nine or more weeks behind. Other key metrics reviewed by the company include production schedule accuracy, months of on-hand inventory, bill of material accuracy, total program cycle time, and contract starts.

PPR is tailored after Oliver Wight's world-class MRP approach, which was proven to be a key enabler for companies to achieve Class A, MRP II performance. Since implementing PPR, RMSC has improved on-time contract starts and contractual deliveries; reduced inventory carrying costs and cycle times; and produced realistic, trustworthy schedules. In one case, PPR showed that a cycle time improvement was not being achieved, so the company added an additional metric (pareto analysis of time required to purchase long lead items) to identify the key offenders and target them for special attention.

Synthetic Minor Approach to Title III Clean Air Compliance

RMSC performed a cost-benefit analysis to determine whether the company should voluntarily limit its hazardous air pollutant (HAP) emissions to avoid

costly regulatory requirements, or pursue a restrictive, less production-focused method available under the major source status. The company opted for the Synthetic Minor approach, and agreed to voluntarily restrict its emissions below the threshold for the major source status. This approach allows the company to avoid prescriptive and intrusive requirements imposed under that category.

The company's incentive for pursuing the Synthetic Minor status for HAP was to avoid the National Emission Standard for Hazardous Air Pollutants' (NESHAP's) requirements, and to reach the maximum achievable control technology legislated for the aerospace industry. These regulations restrict a facility to a maximum of 25 tons of HAPs per year, which narrowly qualified RMSC's facility. The additional levels of compliance, capital costs for abatement equipment, and elevated need for comprehensive record keeping made the Synthetic Minor approach more attractive to the company.

The NESHAP standard is unique because once a facility commits to these requirements by choosing the major source status, there is no opportunity to alter that decision. This stringent regulation is binding regardless of whether the initial criteria used to determine a facility's status are still applicable in the future. In addition, the NESHAP standard addresses all sources of HAP emissions, regardless of whether they are production related.

The Synthetic Minor approach enables RMSC to validate its low levels of pollutants via reports to show the facility's chemical usage and emissions. The company also had to enhance its existing database system via capital expenditures to specifically track all HAP fuels and chemicals issued and stored at the facility. However, the costs incurred through the Synthetic Minor approach were much less than if the company had chosen the major source status. Additional benefits include a near real-time snapshot of HAP containing materials on-site, and a consistent source of valuable information for prioritizing P2 opportunities and evaluating the effectiveness of implemented P2 projects.

Test Equipment Design

In 1996, RMSC created a development process for automated test equipment (ATE) in accordance with the company's IPD process, but tailored to meet ATE characteristics. This process provides a structured approach for ATE development. The user can design and fabricate the ATE within a short cycle time to coincide with production requirements and best commercial practices.

RMSC's ATE development process creates a vehicle for fabricating low cost, standardized ATE throughout the Corporate enterprise. Additionally, the process has provided the groundwork for deploying Corporate initiatives in a consistent manner over the Intranet, complete with detailed, easy-to-follow, how-to instructions for addressing various issues (e.g., design margins, testability, producibility, correlation, fixturing/cabling). The ATE process also gives RMSC an effective way of aligning the company's goals to support the programs' goals via metrics and customer feedback.

Since implementing the ATE process, RMSC realized a 30% savings in labor and material expenditure on selected programs, and projects a 10% savings on future programs. Other benefits include supplemental gains in the areas of employee communications, efficient distribution of organizational data, and corresponding facilitation of the company's continuing ISO-9001 registration process.

Transition Toolkit for Restructure Activities

After the Raytheon/Hughes merger in 1997, the Raytheon Corporation decided to consolidate and relocate all of its missile functions to the Tucson facility. RMSC wanted to ensure that EH&S issues were being addressed during these activities, so the company set up a special EH&S transition taskforce for developing guidelines. As a result, the taskforce developed a unique transition toolkit, which was distributed to the 13 relocating missile programs.

RMSC's proactive transition approach captured all data needed for permit and production modification. A comprehensive checklist was developed by the restructuring team for use by the product line points of contact (POCs) who supported the transitioning programs. Specific concerns addressed by RMSC included air quality permit revisions, explosive site approval, and new/modified manufacturing processes. Any deviation from RMSC's existing manufacturing baseline (up or down) needed to be assessed for its impact against existing permits.

Using a standardized approach, POCs communicated all transitioning information (e.g., EH&S objectives and requirements, reasons for implementing the toolkit) to their respective programs. Up-front, high-level program information was required to forecast potential EH&S impacts. Since the manufacturing

activities of all the transitioning programs are collectively viewed by the regulatory agencies as a single source, all gathered data needed to be collected in similar terms so the overall EH&S impact could be assessed. RMSC's toolkit provided the means to verify that all pertinent data was collected.

The transition toolkit provided guidance and direction for the programs relocating to the RMSC facility. In addition, the toolkit captured and collated data for RMSC which allowed the company to avoid long permit revisions and transition schedule delays. Current program baseline information and anticipated deltas with respect to air emission, hazardous materials, and explosives were required from each transitioning activity. The transition toolkit facilitated the roll-up of EH&S information from an extremely diverse group of manufacturing activities while maximizing the limited resources available to complete the task.

Facilities

Acquisition Pollution Prevention Initiative

Acquisition Pollution Prevention Initiative (AP2I) is a joint DOD/contractor program used to reduce/eliminate pollution from the life cycle of military products. In 1997, the Under Secretary of Defense for Acquisition Reform called for the reduction/elimination of hazardous materials from the design, manufacturing, and logistics areas. NESHAP required this task to be completed by September 1998. RMSC addressed this issue by using AP2I to establish the Elimination of VOC Project and set up an IPT. This team consisted of representatives from the Defense Contract Management Command (DCMC), Army, Air Force, Naval Sea Systems Command, Naval Air Systems Command, and RMSC.

In the past, attempts to simplify product line processes typically failed due to the wide range of individual program variation and the multiple government organizations involved in the decision. Each program had its own test requirements, program office, and technical agencies. Joint test protocols appeared to be a sensible solution, but agreement was difficult to reach. Through the AP2I project, the IPT focused on identifying and validating alternative materials, processes, and technologies to minimize/eliminate the use of liquid paints. Between January and April 1998, the IPT selected candidate processes, proposed conditions and test parameters, defined environmental variables, refined and investigated alternatives, clarified a concept paper, identified minimum test requirements, and developed the Joint Test Protocol. In addition, they established a performance-based requirement for coatings as a function of environment and usage. Proposed processes included no paint, powder paint, decals, and appliques.

The Elimination of VOC Project established coating requirements as a function of usage and environment. Design guidelines help users select the most effective coating system. A missile that is positioned on an aircraft at sea will have a different coating requirement than one sealed in a desiccated launch tube. The proper coating is selected based on system needs, which lowers system costs. New technology, such as decals and appliques, provides cheaper coatings and eliminates VOC emissions.

The AP2I methodology provides a flexible and fast method for adjusting existing projects or developing new ones. This approach assembles a technical team of representatives from various disciplines who view the problem based on system needs not historical requirements. The objective is to determine maximum benefit at minimum cost. Key elements for successful implementation of AP2I include creating a single point of contact team, focusing on minimum test requirements, completing technical and business plans in minimal time, and providing maximum P2 benefits at minimum cost. Since implementing the Elimination of VOC Project, RMSC eliminated 4.3 tons of VOCs and reduced weight, cycle time, and cost. Total development costs were $200,000. The Elimination of VOC Project was submitted by DCMC for an annual AP2I award.

Chemical Strategies Partnership

Raytheon Corporation launched a major effort to reduce its operating costs through full/partial closures of 26 facilities and 16 offices. When complete, this effort will result in a 20% decrease in facility space, a 10% reduction in personnel, the creation of Centers of Excellence, and aggressive measures for reducing material costs. In this context, Raytheon set up a Chemicals and Gases Technology Team to handle cradle-to-grave management of production/non-production chemicals, bulk/cylinder gases, and chemical waste services across the corporation.

Since 1996, RMSC's manufacturing plant at AFP44 has been a partner in the Chemical Strategies Partnership (CSP), sponsored by the PEW Charitable Trusts. The sponsor is geared toward identifying the existing drivers of chemical usage, making these drivers known to industry, and bringing tools/exper-

tise to the partners. CSP's goals are to reduce the use and release of chemicals; restructure the relationship between partners and chemical suppliers; and foster a corporate organizational commitment to integrate cost-effective P2 into strategic business objectives. By pursuing these avenues, CSP strives to establish EH&S as a business driver.

In the past, chemicals were viewed as a way to produce quality products in a cost-competitive and timely manner. Many businesses looked only at the procurement aspect of chemical management, and failed to see the associated costs which materialized over the life cycle of the chemical. Today, the manufacturing sector is redefining how chemicals are sold and used. Supply chain management now manages chemicals throughout the commodity's entire life cycle (e.g., procurement, inventory, internal delivery, emergency response, handling, use reduction, monitoring, reporting, collection, disposal). By improving the chemical management system for each part of the life cycle, businesses can reduce costs, enhance production quality and efficiency, and improve safety and environmental protection. The CSP methodology (Figure 2-5) addresses these issues by incorporating process-level material and cost accounting. The methodology involves mapping the chemical process, reviewing the production history, and calculating the material output as accurately as possible. Next, chemical management cost accounting is developed to determine the actual costs for each chemical at every stage as well as identify how much chemical waste occurs at the manufacturer's facility. If 35% of a company's material is waste and half of this waste requires costly handling/disposal efforts, then the manufacturer will be motivated to reduce the consumption of that material.

RMSC performed materials and cost accounting at its printed wiring board shop, and estimated its savings at $400,000 annually. Currently, the company is working with its suppliers to develop incentives and renegotiate contracts. RMSC plans to benchmark best practices for chemical management; publish materials and cost accounting results; and distribute a how-to manual with sample supplier contracts. Supplier involvement is critical because it creates incentives to reduce chemical use; allows the company to concentrate on its core business; and focuses on function instead of products. Another partner in CSP developed service contracts with its suppliers. As a result, this partner reduced procurement and chemical management costs by 60%; decreased procurement time from 15 days to one; achieved a 20% reduction in chemical purchasing costs via consolidation; and regarded the chemical management program as being instrumental in obtaining its ISO-14001 registration.

RMSC presented the CSP methodology to the Chemicals and Gases Technology Team. As a result, a single Tier I supplier was chosen to handle the corporation's chemical, gas, and waste services. Supplier compensation is based solely on incentives. This approach will enable Raytheon to become an industrial leader in hazardous chemical use reduction.

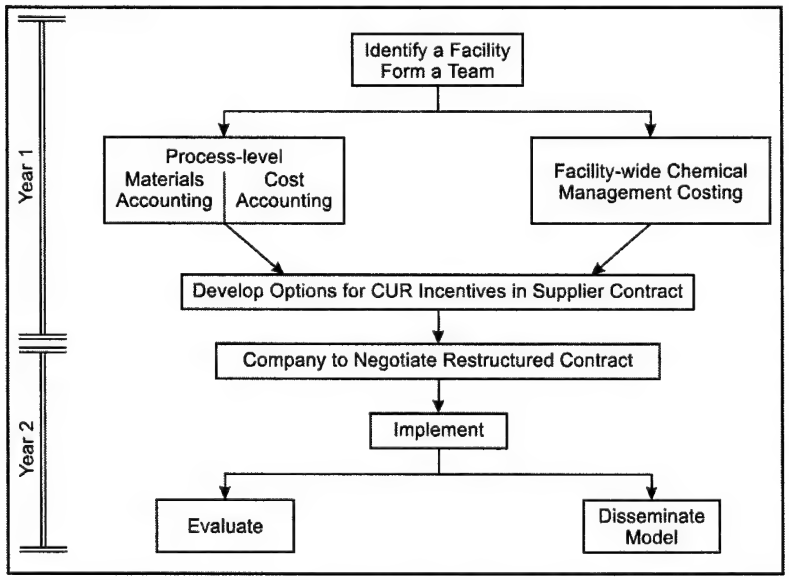


Figure 2-5. Chemical Strategies Partnership Methodology Block Diagram

Dual Phase Extraction Concept for Remediation

Dual phase extraction (DPE) is a means for effectively extracting large quantities of TCE and other volatile solvents from below the water table at former solvent disposal sites. DPE works hundreds of times faster than other pumping methods in removing solvents from the contaminated groundwater plume. Since these solvents have very high vapor pressures but are relatively insoluble in water, ordinary soil vapor extraction is not effective.

RMSC developed DPE as an enhancement to its pump-and-treat remediation system. The technique

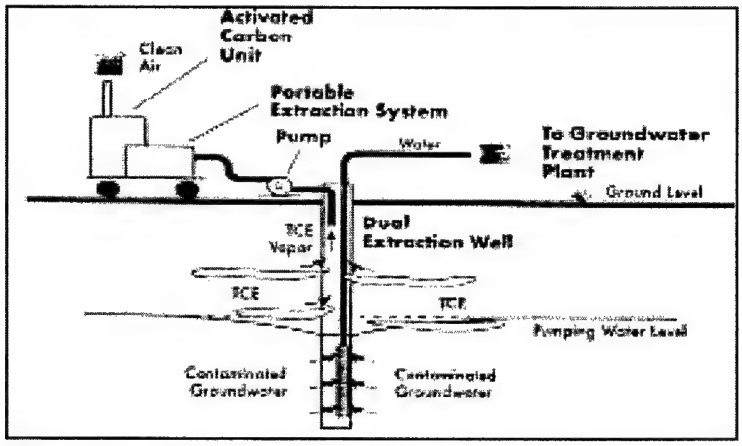


Figure 2-6. Dual Phase Extraction Concept

(Figure 2-6) involves evacuating air (vapor extraction) from the casing of a pumping groundwater extraction well. The pumping lowers the water level in the well and exposes solvent-contaminated soils to the air. The vacuum also causes the solvents to evaporate. As the air is sucked from the well, the vapor is pulled out and captured within granular activated carbons (GACs). RMSC's cost of adding pumps to its existing extraction wells was approximately $15,000 per pump.

In the northwest section of RMSC's facility lies a 65-acre shallow groundwater zone. Here, a 20- to 40-foot layer of perching clay (reddish brown clay/sandy clay) runs laterally at a depth of 75 to 80 feet below the ground surface. This clay is overlain with sand and clayey sand. The shallow groundwater occurs in and above the perching clay at depths of 55 to 98 feet. The water levels in the shallow groundwater zone fluctuate seasonally in response to surface water recharge. The upper zone of the aquifer extends from 100 to 140 feet below the ground surface to a depth of 200 to 220 feet. This zone is underlain by a thick sequence of clayey sediments (known as the Aquitard Unit), which extends to a depth of 350 feet. Below the Aquitard Unit, the sediments consist of thin lenses of sand and gravel within predominantly clayey sand and sandy clay. The reclamation well field consists of 21 upper zone extraction wells, four lower zone extraction wells, nine shallow groundwater zone extraction wells, and 21 recharge wells.

Geologic conditions favor DPE at this site due to the existence of the clay bed at the top of the aquifer, which traps non-aqueous phase liquids. The heavy/clay soils also favor this method. Although TCE is denser than water and relatively insoluble, the 20 parts per million solubility exceeds the drinking water limit of five parts per billion. Operating at a pressure of 12 inches of mercury, the pump vacuum removes TCE at a rate of 120 pounds per month. When the water table level of the aquifer is drawn down below the location of the TCE, the DPE process is triggered to begin.

Vapor is discharged into primary carbon vessels until the vapor concentration of the vessel effluent matches the concentration of the vapor entering the vessel. This ensures maximum saturation of the GACs. Next, the primary vessel is removed and the partially-saturated secondary vessel is moved into the primary vessel's position. A new carbon vessel is placed in the secondary position and the process is repeated. The spent primary carbon vessel is shipped off-site for regeneration. The carbon supplier replaces the saturated units with dry ones, freeing RMSC from the liability of this material. Activated carbon is used in roll-offs of 10,000 and 20,000 pounds. At a cost of $1.25 per pound, carbon is the best alternative despite being the highest, single-cost material for operations and maintenance. RMSC experimented with various-sized pumps and synthetic resin filters, and determined the best arrangement consisted of two medium-sized pumps with activated carbon to remove chlorinated hydrocarbons. The company's success with DPE is indicated by the following sites' removal rates: 33,844 pounds (TCE) at Site 2/E-16; 3,308 pounds (TCE) at Site 2/E-20; 1,714 pounds (TCE, DCE, trichloroethane, freon 113) at Site 3/E-19; 4,724 pounds (TCE, DCE) at Site 5/E-12; and 1,605 pounds (TCE, DCE) at Site 14/shallow groundwater zone.

Extraction and Recharge Concept for Remediation

The disposal practices of the 1950s created a contaminated groundwater plume in the northwest section of RMSC's facility. The plume is located 500 feet below the ground surface, and covers a 65-acre area. To clean this contaminated groundwater, RMSC uses a pump-and-treat remediation system. In addition, the company implemented a recharge field at this site to contain the groundwater and stop its northward migration (500 feet per year). The reclamation well field consists of 21 upper zone extraction wells, four lower zone extraction wells, nine shallow groundwater zone extraction wells, and 32 recharge wells.

The pump-and-treat remediation system works in conjunction with the recharge well field to re-inject

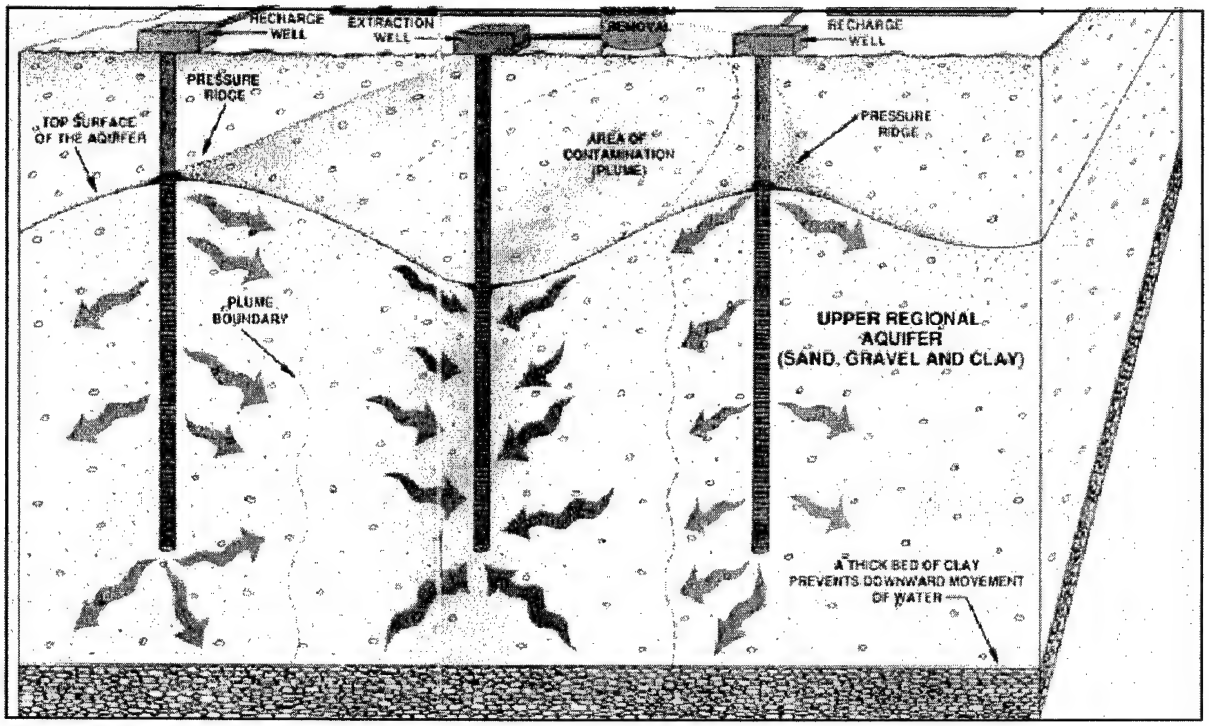


Figure 2-7. Aquifer Cross-sectional View

groundwater back into the aquifer after contaminants are removed (Figure 2-7). This technology significantly increased the remediation rate of the groundwater in the aquifer beneath the plant. In addition, RMSC reduced its expected completion time for groundwater cleanup from 50 to 15 years, and removed more than 20,000 pounds of contaminants from over 16.8 billion gallons of groundwater over an 11-year period.

The extraction and recharge concept for remediation provides many advantages for RMSC. Among the benefits are containment of the groundwater plume; an increased rate at which groundwater moves within the aquifer toward the extraction wells; a flow rate that is not restricted by the use of groundwater after it is cleaned; and a flushing effect within the subsurface which expedites contaminant removal whenever the water table rises around the recharge wells. In addition, the company effectively doubled the gradient of water at the extraction wells by mounding the water from recharge wells.

Household Hazardous Waste Collections

Pima County has operated a household hazardous waste (HHW) drop-off center since 1988, and won various national awards for its recycling programs. The County's efforts include a HHW program which provides waste collection and educational services, and a Drop & Swap program that allows participants to drop off unwanted chemicals and/or pick up free supplies. RMSC has extended these programs to its employees by creating a partnership with Pima County and the City of Tucson.

Through this partnership, RMSC holds a HHW collections event, three times a year, at its facility. On these designated days, employees bring unwanted hazardous chemicals from home for disposal at RMSC. This approach reinforces proper HHW handling/disposal practices at home, and provides a great opportunity to team with County/City officials on safety and environmental issues. During the first year, the company collected 25,901 pounds of unwanted hazardous material (e.g., batteries, paint products, used oil) from its employees' homes and garages. A questionnaire, circulated during the company's initial events, confirmed that large quantities of chemicals would have been illegally dumped into Arizona's deserts, ravines, and sewers without this HHW program.

RMSC's HHW collections event attracts a high percentage of participants every year. Employees remark that the event helps them feel good about recycling and gives them a source for obtaining

environmental, health, and safety information. Participants also receive an inexpensive "I have recycled my hazardous waste today" label to proudly wear throughout the day.

RMSC's HHW outreach program assists the community with environmental education by promoting home safety and recycling practices. The company is responsible for furnishing the collection site, publicizing the upcoming event, and providing environmentally-trained employees to help the County HHW workers safely collect the chemicals during the event. In return, Pima County and the City of Tucson pay the costs associated with collecting, packaging, transporting, and disposing the collected materials.

Inventory Management and Parts Presentation

Prior to 1996, RMSC used a traditional inventory management system which relied on central stores for all incoming material. Here, items were received, unpacked, inventoried, stored along with other factory parts orders, and kitted on demand for a particular assembly/subassembly. To maintain efficiency in these stores, kits were batch/lot-processed according to weekly or monthly factory production requirements. Drawbacks to this system included inaccurate inventory counts; inability to handle the quick turnaround needs of agile manufacturing; higher product costs caused by unnecessary handling; and numerous delays when shipping the product.

In February 1996, RMSC began using a point-of-use inventory management system for its Phalanx and RAM Launcher programs, which mirrors the IPT concept used throughout the agile factory. The material storage areas are placed adjacent to the production floor, and color-coded to identify the corresponding team and assemblies. Parts for the factory floor can be pulled within hours, and replacement parts can be issued within minutes. This approach prevents work stoppages on the production floor, and promotes kitting for one instead of weekly or monthly production requirements. RMSC also instituted a Supplier Managed Inventory program for line stock (or common stock) materials. These materials are delivered directly to the production floor on an as-needed basis by the common stock supplier. Since implementing these changes in its inventory management system, RMSC reduced total kit cycle time from 14 days to less than one hour; decreased replacement part cycle time from five/seven days to less than one hour; increased inventory accuracy to 99%; and minimized kit part shortages.

Next, RMSC undertook a Parts Presentation program to enhance the efficiency of its agile factory, complement its inventory management system, and further reduce cycle time and costs. A team of production assemblers and support personnel studied how material was delivered to the assembly floor, and analyzed the line stock requirements for each cell. As a result, custom-part bins were developed and installed at all workbenches in every cell. These bins contain only the line stock needed at a particular work location. The team also recommended using kit sizes of one to minimize work in progress (WIP) on the production floor. RMSC designed a visual parts presentation vehicle (PPV) with part specific slots for each and every line flow assembly. By glancing at a PPV, the assembler can quickly determine which kit items are missing.

Since implementing the Parts Presentation program, RMSC significantly reduced WIP on the production floor. In addition, the company reclaimed approximately 25% of its production floor space; eliminated production floor inventories; decreased average assembly cycle time by 50%; and minimized the misplacement of parts and hardware.

Multi-Missile Manufacturing Facilities

In 1995, RMSC operated its RAM and Maverick missile programs as separate initiatives. Each program used its own test and assembly personnel, test equipment, and support tooling to produce a finished product. However, projected reductions in program budgets, quantity requirements, and workforce size indicated that RMSC needed to change its operational methods if the company wanted to maintain its high level of customer support. As a result, RMSC developed a plan to reduce costs and improve the efficiency of its personnel, equipment, and facilities.

The plan called for developing two multi-missile manufacturing facilities. One facility produces, assembles, and tests the guidance and control sections for the RAM, Maverick, and AIM-9X programs. The other facility performs final assembly and delivers the end products to the customer. These joint, integrated, multi-project facilities are especially beneficial to small programs or ones with intermittent production schedules. By combining the RAM, Maverick, and AIM-9X programs, RMSC reduced factory floor space by more than 17,500 square feet. Test equipment, tooling, and fixtures are now maximized among the programs. Personnel are also cross-trained, so they can work on any aspect of these programs as workloads and priority requirements dictate.

RMSC saved approximately $1 million since implementing its multi-missile manufacturing facilities. This approach creates a multi-functional team structure; promotes the joint use of personnel, equipment, and facilities; and provides greater cost benefits for all.

Remediation Control Room

RMSC's Tucson facility has been manufacturing electronics since the 1950s. Like most manufacturers at that time, the company used TCE to remove oils from its circuit boards, and employed on-site land disposal practices. As a result, the soil and groundwater underneath AFP44 became contaminated. In 1981, the Air Force and Hughes (now Raytheon) began researching ways to clean these areas, and initiated a small pilot program in 1985 to test their proposed solution. The project's success led to the construction of a sophisticated, large-scale treatment plant in 1987. Today, RMSC features many remediation methods and technologies to purify contaminated soil and groundwater at AFP44. The company also recharges aquifers with cleaned water, releases cleaned air into the atmosphere, and destroys VOCs at an off-site facility.

The Air Force funded the construction of AFP44, and designated community outreach as an important aspect of the facility. AFP44's Remediation Control Room provides visitors with a multitude of displays, including a storyboard on the remediation process; background information and benefits of the process; and monitors extraction/recharge rates for pumps in operation at the wells. The Remediation Control Room is regularly visited by middle and high school classes, and is part of the environmental science curricula at two universities and one community college. RMSC tailored the Room to be instructive and educational to all visitors, regardless of their level of expertise. The facility's architectural design, using open spaces and glass viewing windows, provides visitors with easy accessibility to the displays and encourages them to interact with remediation technologies and applications. As a result, the community can see firsthand the company's success at AFP44.

Adjacent to the Remediation Control Room is the Environmental Laboratory, which provides analytical support for operating RMSC's groundwater remediation project. Built in 1986, this 2,400-square foot facility features a glass wall so visitors can observe the Laboratory's activities. The Environmental Laboratory contains a wide array of organic/inorganic analysis instrumentation including gas chromatographs, mass spectrophotometers, atomic absorption spectrophotometers, and inductively-coupled plasma spectrophotometers. An Information Management system allows the Laboratory to gather and process data from these instruments as well as log, track, and generate reports.

In addition, RMSC established quality control guidelines to ensure that all work performed at AFP44 is analytically correct and acceptable to regulatory agencies. Typical activities with quality control limits include analysis of blanks, duplicates, spikes, surrogates, and certified reference samples at a frequency of 10% of all samples run. Data quality is also confirmed by splitting and sending 10% of the collected samples to an independent certified laboratory, and by the company's participation in state and EPA Performance Evaluation programs. The Environmental Laboratory successfully obtained licenses for drinking water analysis from the Arizona Department of Health Services in 1987, and for wastewater and hazardous waste in 1992.

Stinger Training Room and Agile Factory

Recently, RMSC completed the innovative installation of a training process for the Stinger missile assembly operations. This process ensures that assembly and test personnel receive the latest training, and provides the company with a cadre of cross-trained individuals who can perform all of the operations for updating/building the subassemblies of the Stinger missile.

As RMSC incorporates newer versions of the Stinger missile into its operations, numerous obsolete and scrap subassemblies/parts are accumulated. Instead of discarding these items, the company uses them to build mockups of the missile's assembly stations for training purposes. Each station also contains the necessary tools, test equipment, and process instructions for that operation. The Stinger Training Room simulates RMSC's Agile Manufacturing area, and allows personnel to learn or practice new techniques and processes (e.g., assembly/disassembly, testing, troubleshooting) on actual hardware. In addition, employees are cross-trained in all functions of the Stinger's assembly operations. With this training, RMSC assures that the desired results of Agile Manufacturing initiatives will be realized.

Besides the technical training room, RMSC's Agile Manufacturing area also utilizes new line flow bal-

ance techniques; a self-contained supermarket for required materials; a flexible floor layout and adaptive infrastructure; lean tooling; workplace organization; and an effective shop floor control system. All employees in the factory are fully trained in the processes and theories of Agile Manufacturing. By implementing Agile Manufacturing methods and tying this focus to the technical training room, RMSC has realized significant savings in the Stinger missile assembly operations. These successes, after only 13 months of implementation, include:

- Factory WIP reduced by 84%
- Pilot area WIP reduced by 87%
- Inventory turns improved by 255%
- Factory cycle time improved by 81%
- Pilot area cycle time improved by 89%
- Factory WIP to sales improved by 89%
- Factory delinquencies improved by 69%
- Pilot area delinquencies improved by 98%

Strategic Energy Management Plan

In 1985, RMSC initiated the Strategic Energy Management Plan (SEMP) which greatly reduced energy usage, minimized capital equipment investments, produced a savings of $15.6 million (as of 1996), and avoided 369 million pounds of air pollutants that would have been generated at the power plant. These significant savings were achieved through a series of energy reduction strategies including occupancy sensors, fuel switching technology, plate and frame heat exchangers, thermal energy storage systems, variable frequency drive technology, lighting retrofitting, peak shedding, and management planning.

RMSC's largest savings ($2.8 million) occurred in 1996 after partnering with an Energy Services Company (ESCo) that utilized Energy Saving Performance Contracting (ESPC) methodology. Initially, ESCo conducted an audit at RMSC to analyze energy usage and how best to apply current technologies to maximize the savings. After completing the audit, ESCo proposed a five-year contract to RMSC that would reduce cost by no less than $400,000 annually without the need for large capital investment dollars. This proposal also stipulated repair/replacement of low efficiency apparatus throughout the plant, full compliance with applicable regulations, and extensive training for employees on how to maintain peak performance. The savings were guaranteed by ESCo, and a check would be written to RMSC regardless of how much money was realized though the implemented energy saving strategies. In return for ESCo assuming all the risks and substantial costs of capital improvements, RMSC agreed to significantly share the reward of cost savings with ESCo over the length of the contract. Once the contact is fulfilled, RMSC will reap all the rewards and costs savings (currently $2.6 million annually) through the lifespan of the equipment. This win-win strategy allows RMSC to accelerate its energy savings and equipment programs, while proactively promoting good stewardship of its capital investments and environmental resources.

One of RMSC's most successful energy saving programs of SEMP is the thermal energy storage tanks. The concept is simple. Cold water is generated during off peak hours when electrical usage is low and the cool ambient condition of the night exists. Large volumes of chilled water are then stored for daytime usage. To be successful, a large water storage tank is needed to house the chilled water until it can be rapidly heated during the workday. The original proposal called for a $2 million capital investment with an eight-year payback period. However, the Air Force considered this payback period to be too long. RMSC engineers did further research, and discovered an existing 1.7-million gallon storage process tank which they felt could be converted to store the chilled water. After re-engineering the project, the engineers realized that the tank could be used as is, and cut the project's investment cost down to $1 million. The Air Force approved this proposal, and gave RMSC permission to proceed. The cost savings realized from this single project alone will exceed $265,000 annually. Had this project been implemented when first proposed in the early 1990s, the company would have realized a savings of more than $2 million by this time.

Energy savings strategies such as those of SEMP are sound business decisions that make good sense from cost and environmental standpoints. SEMP promotes sound, proven, and demonstrable technologies that guarantee a tremendous return on investment. The cost of capital equipment dollars are greatly reduced or eliminated. RMSC's decision to partner with ESCo resulted in guaranteed savings to the company that would have otherwise been paid to the utility company. SEMP saves dollars, reduces negative environmental impact, provides a guaranteed return on investment, and promotes proactive capital equipment investments.

Logistics

Advanced Modular Factory

RMSC received an award from the Air Force's ManTech Project for the Advanced Modular Factory (AMF). The primary objective was to develop lean strategies for the AMRAAM program which would reduce product lead times and eliminate critical path waste. The project also focused on the relationship between RMSC and its suppliers.

The AMF project began by analyzing AMRAAM's product lead time drivers. As suspected, external suppliers were the primary consumers of the critical path. Data indicated that supplier lead times accounted for 70% of the path, procurement consumed 20%, and internal factory cycle times used the remaining 10%. To reduce lead times, RMSC concentrated on strategies that would modify business practices and industrial processes. Business practices included business strategy innovations and rapid response procurement processes. Industrial processes included kaizen workshops to eliminate waste, since RMSC was the process owner for the entire supply chain. Once the methodologies were chosen, RMSC employed them on AMRAAM items which had the longest supplier lead times, progressing successively to those with shorter requirements as improvements developed. Each item was analyzed, sometimes to the second- and third-level supplier, to identify and prioritize potential corrective actions. In addition to supplier and procurement solutions, the company conducted workshops and lean training at supplier sites, and hosted supplier visits at RMSC. These strategies enabled participants to gain awareness and understanding of the overall program activities.

Since implementing the AMF project, RMSC created supplier agreements with efficient production schedules, identified opportunities for parallel rather than serial production, eliminated artificially inflated lead times, improved production processes by suppliers, and achieved better raw material procurement times. In addition, the company issued direct strategic agreements for raw materials and letter contracts for long lead items. Initial lead times were decreased by about 20%, with an additional 25% reduction in product lead times for the next AMRAAM lot. RMSC continues to apply the AMF strategies to obtain even greater reductions in lead times and critical path waste.

Management

Agile Improvement Process

RMSC began implementing its Agile Initiative in 1995 as a means to improve performance, and eliminate waste in a rapidly growing and changing company. The company developed its approach through benchmarking and by adapting proven concepts to fit its culture. RMSC wanted to develop a manufacturing system that was both lean and flexible, and based its Agile Initiative on an adaptation of General Motor's and Toyota's Competitive Manufacturing Principles. The lean element is focused on eliminating waste wherever it occurs. The agile element is focused on creating a capability to quickly react to the changing environment by becoming highly responsive to customer needs; utilizing speed as a competitive advantage; and reducing manufacturing lead times by 50%.

RMSC developed a seven-phase systematic approach to improve quality, cost, responsiveness, and customer satisfaction through the elimination of waste and the total involvement of all employees. The seven phases of the agile processes are broken down into 45 steps (or strategies) to implement the phases. In addition, there are hundreds of substeps which provide detailed task-by-task descriptions of activities. All of these components are tailored for implementation in each of the major manufacturing areas and centers of the company. Since 1995, the process has been implemented, or is in the process of being implemented, in 15 factories within RMSC. Each factory is committed to implementation, and began the process with the assistance and guidance of the company's agile planning team. The agile planning team works with each factory to train and establish a 15-member core team. The core team then establishes other teams within the factory, and conducts training, benchmarking, strategic development and planning, and other activities and processes needed to implement agile and lean concepts in the factory. This approach is designed to lead to a complete cultural change within a six- to twelve-month period.

Significant improvements have been made in all factories through the implementation of the Agile Initiative. RMSC believes that this approach was a key enabler leading to the company winning the 1997 Arizona Governor's Award for Quality. Since 1995, RMSC has made rapid strides in making the Agile Initiative an integral part of the enterprise which is embedded in every aspect of manufacturing. This approach provided RMSC with the capability to thrive

in a continuously and unpredictably changing environment, as well as the ability to operate profitably in the company's many competitive markets. As implemented at RMSC, the Agile Initiative offers a structured, sensible, easy-to-follow process with extensive documentation and training. The process focuses on fixing problems rather than working around them, and encourages operator involvement. In addition, this initiative produced major reductions in cycle times, inventory, and WIP as well as standardized processes and techniques. The Agile Initiative continues to be a successful approach to eliminating wasteful practices while responding effectively to changing business and customer requirements.

Blue Criteria

RMSC has traditionally applied the commonly used red-yellow-green color scheme to visually depict performance criteria. Red indicates non-compliance or high risk; yellow indicates substantial compliance or low risk; and green indicates full compliance with established criteria. In 1997, RMSC added a new color indicator, known as blue criteria, to the traditional color scheme.

At RMSC, blue indicates established performance criteria that exceeds the acceptable industry or government standards. The following are typical examples of RMSC's criteria for key government-specified Material Management Accounting Standards:

Inventory Accuracy:
- Red is less than 90%
- Yellow is 90% to 94.9%
- Green is 95% to 99%
- Blue is 99.1% to 100%

On-Hand Inventory:
- Red is 5.0 or greater
- Yellow is 4.0 to 4.9
- Green is 2.5 to 3.9
- Blue is 2.4 or less

RMSC implemented the blue criteria approach to support its world-class business strategies. Under acquisition reform initiatives, blue criteria provides a means to identify candidates for reducing government oversight without adding risk to the customer. Reductions in oversight translate directly to reduced manpower and costs, and greatly simplify management review. RMSC is an industry leader in developing and applying criteria that exceeds government standards throughout its entire business operations structure.

Career Enrichment Program

In 1987, the Career Enrichment Program (CEP) was started as a partnership between RMSC and the International Association of Machinists and Aerospace Workers, Local 933. CEP operates as a pay-for-knowledge plan which enables hourly employees to obtain certifications for particular job units by completing prescribed courses. In addition, the program addresses bargaining unit employee participation, career development, compensation, and labor utilization. Prior to CEP, there was little communication between bargaining unit employees and management, virtually no defined hourly career paths, and no formalized incentive system to enhance skills. These factors, coupled with numerous job classifications and a rapidly changing contractual and technological manufacturing environment, created tentative job security for employees.

RMSC designed CEP to establish a flexible workforce, meet the changing contracting environment, and eliminate the perception that bargaining unit employees were underutilized. This employee/management partnership encompasses many avenues including career paths, pay for skills, workforce flexibility, job satisfaction, contributions, marketability, commitment, and employee empowerment for self-directed careers. The program uses the Main CEP and five Family Committees (assembly, fabrication, maintenance, process, and support job classifications). These committees design classes and certification challenge tests; develop unit descriptions; and utilize hourly employees as CEP instructors and subject matter experts.

Since implementing CEP, RMSC enhanced its job environment and significantly improved its labor utilization and flexibility. Occupation categories were dramatically reduced from 132 to 46. More than 400 salary tasks are now assigned to hourly employees, which reduced task duplication and costs. In addition, the number of certifications held by employees increased, thereby elevating the employee skill level and flexibility, and making them less vulnerable to reductions in force. CEP's success is evident and well documented. To the program's credit, its leaders and participants recognized the need to address evolving requirements; prepared their issues, concerns, and recommendations; and are ready to move forward to keep this successful program current and responsive to present and future work environments.

Connecting to the Community

RMSC uses Connecting to the Community activities as an innovative and effective way to interact with the surrounding community. Over the years, these outreach activities have produced quantitative and qualitative results, and helped establish goodwill between the company and the community.

In 1994, RMSC initiated a Grant Application Process to standardize the company's charitable giving program. Two years later, the company created a Contribution Committee, comprised of company management professionals and hourly employees. Since their implementation, these activities have been expanded and refined to meet the critical needs of the surrounding community as well as typify the goals and objectives of the company. This concentrated effort, to strategically align company goals and community needs, has resulted in a 75% increase in RMSC's approval rating.

To broaden its connection to the community, RMSC began providing in-kind contributions and resources through leadership gifts. In 1997, the company began the Quality Function Deployment (QFD) program as a way for community groups to get together and address critical community issues. This highly successful program provides an alternative avenue for diverse groups to interact and make systematic community changes. In addition, QFD helps RMSC involve itself with key community issues, and strengthens the company's standing in the community as a credible partner. Another aspect of RMSC's activities is its community awareness partnerships, such as Support-a-Park, Power of Community, and Christmas in April. These projects are just a few examples of RMSC's efforts to build goodwill, trust, and connectivity by teaming with the community to help enhance the lives of youth, the disadvantaged, and the elderly.

RMSC's Connecting to the Community activities promote synergies and understanding between the company and the community, as well as between employees and managers as they work side-by-side. Each year, the number of volunteers and corporate commitments continues to increase. RMSC's proactive approach demonstrates its willingness to meet and work with the surrounding community.

Electronic Commerce

Electronic Commerce is an efficient business system that operates in an electronic environment. The system establishes electronic user relationships and authorizations; promotes electronic data interchange (EDI); uses security to protect proprietary data; employs modern search algorithms so products can be built faster and better; and saves time and money by reducing paperwork.

RMSC heavily invested in the development of an extensive Electronic Commerce system. One of the company's top requirements was that the system be in compliance with the Contractor Integrated Technical Information Service (CITIS). Many government programs are now requiring the use of CITIS on new programs. RMSC successfully met its CITIS requirement by implementing the Product Data Management (PDM) system.

The PDM system handles the authentication, encryption, and access to the Electronic Commerce system. What is unique is that RMSC personnel tailored this COTS product to suit the specific needs of the company, and then sent the code to the PDM vendor who put it under configuration control and released it as a new baseline. This achievement enables RMSC to use a standard commercial product, which is tailored to the company's needs and does not need to be maintained by the company. The PDM system is accessible via MAC, PC, and UNIX, and allows users to access any data on the Electronic Commerce system, provided they have authorization. In this way, the company simultaneously has total flexibility and control of the system.

Web-based EDI capabilities are another component of the Electronic Commerce system. These capabilities have overcome many of the high costs and problems associated with earlier versions. As a result, RMSC improved inventory cycles; eliminated manual steps; and reduced errors, delivery times, and costs compared to similar paper-based systems. Security was also a major concern at RMSC since proprietary data would be accessed from outside the firewall. Typically, 128-bit PGP or SSL encryption is used with Netscape browsers to allow for smooth access to all approved users. RMSC's Electronic Commerce system relies on the tailored PDM system for encryption. The PDM system has proven to be so successful at the Tucson facility that Raytheon has assigned the Tucson group to implement PDM as a CITIS solution throughout the corporation.

RMSC achieved a major milestone with one of its missile programs. Using the Electronic Commerce system, RMSC electronically submitted all of the ESSM program's Contract Data Requirements List (CDRL) items to the program office. This electronic delivery was the first of its kind at RMSC. The Electronic Commerce system's IPT structure and sophisticated PDM tool set were integral to the success of this electronic CDRL delivery.

Electronic Expense Report

The Electronic Expense Report is an on-line travel expense reporting system developed by RMSC for its field engineers. Field engineers electronically fill out their travel costs and labor charges on a daily basis. The reporting system takes these entries, and automatically calculates and distributes the expenses to the applicable program's cost account number. The process minimizes errors and reduces turnaround time for processing travel claims.

More than 400 suppliers throughout the United States provide parts and materials for RMSC's missile programs. The company uses 17 field engineers to interact with these suppliers. Each field engineer is required to submit weekly expense reports of their travels, as well as operating supply costs for reimbursement and billing to the appropriate support programs. In the past, field engineers manually made entries and calculations on paper forms, and mailed these to the Travel Office for processing. The Travel Office would match the forms against the field engineers' timecards to calculate the proper distribution of these charges to the corresponding programs. This process was time consuming, error prone, and often inconsistent with the distribution of charges, thus increasing processing time and delaying reimbursement to the field engineers.

In March 1998, RMSC replaced the paper forms with the Electronic Expense Report, created via Excel spreadsheets. Now, field engineers directly enter their charge numbers and hours, as written on their timecards, into the Electronic Expense Report. The system calculates the amount of labor hours for the week, and distributes the expenses to the applicable program's cost account number. These same percentages are also used to automatically calculate and distribute the field engineers' per diem expenses. The Electronic Expense Report looks similar to the paper version, but now the calculations are done automatically, uniformly, and in an easily accessible manner for the Finance department.

The new on-line forms are simpler, and enable the field engineers to fill them out faster. The need to calculate the distribution of expenses on an individual basis has been eliminated. The Finance department now spends less hours per week correcting and rejecting expense reports. Since implementing the on-line system, RMSC eliminated printing costs and streamlined its auditing process. New versions or upgrades of the electronic report can be immediately and consistently implemented by all field engineers. The new system's success has generated an interest in expanding the Electronic Expense Report to other parts of the company.

Enterprise Information Systems Management

In 1997, RMSC developed and implemented the Enterprise Information Systems Management (EISM) concept. EISM is a formal process with supporting infrastructure which maintains baseline configuration and change control of the overall Information Technology (IT) environment. This development grew out of the realization that IT is complex and critical to the overall business, and since IT touches all business areas, decisions made by one service provider could adversely affect a number of other organizations. Accordingly, the EISM concept was adopted to establish a change control process within RMSC, as formally documented in a change control plan issued in September 1997.

RMSC's EISM is a function within the IT Directorate which is responsible for the IT change control process. The process begins when a requesting organization submits a change request (e.g., software or equipment upgrade), along with its completed checklists for software procurement and change preparation. If the request only affects a single functional organization, then it is evaluated by the change review board (CRB) in that organization. If the impact goes beyond a single functional organization, then the Enterprise CRB evaluates the request. Upon approval, the IT provider implements the change, and the EISM librarian records the updated documentation. RMSC uses the Product Data Management system as the repository of all IT baseline documentation and changes.

The EISM process is very similar to the Product Configuration Control systems in place throughout industry. What is unique is the application of proven techniques from the product/engineering environment, and the realization that IT required this level of management. EISM provides the safeguards and controls necessary in an area with enterprise-wide implications.

Five Panel Chart

The Five Panel Chart is a metrics tool used by RMSC management to focus on factual and data-driven issues. This simple, standardized tool is flexible enough to focus on a specific area requiring

management attention (e.g., process improvement initiatives, goals, corrective action). As its name implies, this one-page chart consists of five panels:

INITIATIVE

- Establish a goal;
- Initiative(s) listed should address the key driver(s) in the Leverage Section, and directly impact the achievement of the goal.

LEVERAGE

- Describe the key driver(s) to the process which, if fixed or improved, would be a major contributor to cost reduction;
- How does this initiative improve competitiveness, customer satisfaction, and cost?

CUSTOMER INVOLVEMENT

- Identify key customer(s);
- Must get customer(s) input relative to the initiative(s).

COMMENTS

- Establish a benchmark by which the initiative(s) will be measured;
- List words which are updated monthly to provide current status, discuss accomplishments, address changes, and propose/establish future challenges.

METRIC CHART

- Use specific metric/chart;
- Must include an illustration of a goal line;
- An enlargement of the metric may be included on a second page;
- Below the visual/enlargement, include table of raw data used to derive the metric.

RMSC developed the Five Panel Chart to provide a common process across the company for focusing management attention on critical facts and data. This tool is low tech and easy to understand, but very powerful when applied consistently and uniformly across the business. The chart focuses attention on salient facts/data related to business issues, such as customer satisfaction, competitiveness, and cost. The specific metric/chart provides an effective visual display of status and progress. This practice has demonstrated its adaptability to any organization within RMSC, and provides a consistent tool for presenting key business metrics. The Five Panel Chart has established itself as one of the most effective tools, used by management, to identify and illustrate the state of the business.

Integrated Master Planning System

In 1994, RMSC implemented the Integrated Master Planning (IMP) system as a way of performing program design and improving performance. Acquisition reform and other changes within industry convinced RMSC that the company needed to place emphasis on developing programs, instead of products, to remain competitive. Customers were buying products from those companies which had the best plans for design, manufacture, delivery, and support of their goods and services. A survey revealed that although customers were satisfied with the final products from RMSC, most were dissatisfied with the company's delivery record.

RMSC's IMP system provides potential customers with an understanding of the company's program plan for each product. The IMP system establishes common program goals across teams, and common metrics for all programs/business units within the company. The system is an integral part of the product development and management tool set at RMSC. By using the IMP system, teams can develop effective plans and bids for new contracts, and identify risks early in the planning process. The system is also an effective method for executing a contract upon award.

The IMP system enabled RMSC to increase customer satisfaction and improve its contract win rate. Whenever this system was submitted as part of a proposal, the company won the contract. Having an executable plan in place, upon contract award, has also allowed RMSC to deliver products and services on time. As a result, RMSC is recapturing its customers' trust and attracting new business.

Integrated Process Architecture

RMSC developed the Integrated Process Architecture (IPA) as a framework for integrating its core business processes. This unique, project management tool improves communications and metrics, and addresses advances from an enterprise perspective by fostering the segment-wide implementation of initiatives (e.g., IPD, six sigma quality, agility).

Prior to incorporating IPA, RMSC lacked a strategic approach for implementing a process-centered organization. Although stovepipe improvements were certainly occurring, they lacked the impact of a cohesive, company-wide effort. In light of the flurry of mergers and acquisitions, RMSC found itself with a diverse set of legacy processes from Hughes Missile Systems, Texas Instruments, and General Dynamics. As RMSC attempted to merge its operations, it

became clear that an integrated, strategic approach to business process improvements was not just desirable, but imperative.

The obvious benefits of IPA were the potential to leverage multiple programs via common processes aligned to enterprise level goals; the creation of a structure within which individual process improvements could be implemented; the provision of a structured approach for planning and executing programs; and the communication of overarching goals at every level. IPA increases discipline in the planning cycle at all program phases, and emphasizes metrics as a means of gauging, maturing, and improving processes.

At its core, RMSC's IPA flows from the company's Vision 2000 statement as a necessary means to achieve its goals. Given that those goals would require sweeping changes in business practices, a solid architecture was clearly a requisite for addressing the people, equipment, facility, and technology issues as they arose on an enterprise, vis-a-vis, stovepipe level. IPA's key elements are its relevance to all program life cycle phases; consideration of business gates (e.g., supplier selection or design maturation); core business processes (e.g., new business development, program management, and product development); enabling processes (e.g., human resources, facilities); and enterprise initiatives.

The heart of the IPA is best viewed through decomposition. The architecture is devolved to a series of processes at increasingly lower levels, and finally documented at the unit of operation level by an activity sheet addressing individual process activities. Integrated as they are, the activities must reflect the overarching enterprise goals. Moreover, the employees, customers, and suppliers can clearly understand how their actions contribute to the overall success of the enterprise. To facilitate this communication and improve implementation, RMSC developed an Intranet website, which provides access to IPA at all levels including the activity sheet. RMSC's current plans call for an 80% completion of IPA companywide by April 1999.

RMSC's IPA provides a comprehensive approach to process management and continuous improvements in a large, complex enterprise. This approach addresses all enterprise activities across the total lifecycle in a logical and structured methodology, while fostering communication and understanding among relevant entities. With the advent of the Intranet website, the overall IPA is housed, maintained, and configuration-controlled in an interactive database with search capability, thereby providing easy accessibility to all employees.

Integrated Product Development

In 1994, RMSC responded to increased competition and changing customer requirements by incorporating Integrated Product Development (IPD) as a way to produce higher quality products at lower costs, and in less time. The company is using a whole-systems approach to implement IPD on its existing and new programs.

RMSC began looking at IPD from four perspectives: teams/people; processes; tools; and integrated disciplines. The whole-systems approach resulted in the formation of multi-disciplined IPTs that focus on the product. Processes related to product development were standardized and documented. Tools (e.g., web-based PDM system, IPT handbooks) were developed to make pertinent information available to the teams. The integrated discipline approach allowed RMSC to easily incorporate IPD into the company's organizational strategies and initiatives.

By focusing on the four perspectives, RMSC incorporated significant changes which led to the successful implementation of IPD in all programs. This concept is fully supported by RMSC management, who provides the necessary staffing and resources to execute IPD. In addition, a core group within the company provides ongoing training and guidance to IPTs on the skills and concepts related to IPD. RMSC also modified the reward system to recognize and encourage team participation. Through IPD, employees are given ownership of, and responsibility for, the success of a program.

By implementing IPD, RMSC improved its manufacturing processes and began creating robust designs. This approach allows employees to acquire the skills and knowledge to effectively manage costs, schedules, and risks. Customers and suppliers can monitor the progress of a program as well as work with RMSC personnel to efficiently resolve problems. IPD has improved internal and external communications at RMSC, and provided a positive impact on the company's ability to win new contracts.

International Integrated Product Teams

RMSC's ESSM program must satisfy the requirements of a 13-country North Atlantic Treaty Organization (NATO) consortium. To accomplish this task, the company formed an International Integrated Product Team (IPT) to manage the overall development of this missile program. The International IPT consists of 21 companies in 10 countries which share

the design and production responsibilities for the ESSM program. Several secondary IPTs have also been formed to manage the development and production of the missile's individual sections. To establish a flow of hardware between IPT members, the International IPT setup importing/exporting licenses and developed transportation plans.

Two major enablers of the International IPT are electronic communications and risk management tools. All relevant information (e.g., technical data, presentations) is stored in an electronic database developed by RMSC. RMSC personnel as well as IPT member companies, customers, and suppliers can access this information via a website. By employing electronic communications, the International IPT can use a single technical data package, and keep everyone informed of any changes and progress. RMSC's risk management tools, also accessible via website, allow the International IPT to identify and quantify risks early in the development process. As risks are identified, the priorities for a program can be identified, and the secondary IPTs can be tasked to eliminate or reduce the risk. Since few risks are associated with a single product, the risk management process also facilitates open communication and trust among the IPT members.

RMSC's use of an International IPT fosters technology transfer among the IPT members, and increases the industrial base of the participating countries. The costs associated with the development and procurement of new products and systems are shared among the participants. By using an International IPT, all participating companies/countries are able to field the ESSM program. Due to fiscal constraints, no single company/country could accomplish this task alone. The Navy has recognized RMSC's International IPT for the ESSM program as a model for other international cooperative ventures.

Intranet Website

RMSC developed an Intranet website to promote and manage its Test Equipment Design Centers' (TEDCs') activities. This website addresses many aspects of TEDC activities, including the centers' role in IPD processes; customer awareness and feedback; organization charts; and design standards. The Intranet website allows RMSC employees to easily access any information needed to conduct a TEDC task.

A unique feature of this Intranet website is its automated Document Control system. Most downfalls of programs are caused by poor document control. By utilizing web technology, the Document Control system provides the user with the latest test procedures and drawings on all Special Test Equipment projects. This feature reduces/eliminates the need to keep extra copies of drawings in different areas. Multiple copies often can lead to confusion, resulting in equipment being built to outdated configurations. The Document Control system contains test equipment development processes and tools; COTS standards; fabrication instructions and drawings; hardware and software design reuse libraries; tailored processes owned by other disciplines; and more than 65 test instructions.

Another noteworthy aspect of RMSC's web technology is its integration into the workforce environment. Like other companies' internal web systems, RMSC's Intranet website provides the latest news, features, and announcements. However, the similarity stops there. Operated as a mini world wide web system, this daily-used tool provides employees with numerous capabilities including collecting and verifying information; controlling documents; achieving lean and agile goals; solving problems; collaborating with coworkers; recruiting teams; and preparing for visitors. As a result, RMSC's Intranet website strengthens and promotes communications, collaboration, and integration into the corporate structure and culture.

Since implementing its Intranet website, RMSC estimates a 30% reduction in labor and development cycle times. In addition, future savings across all projects are projected in excess of 10%.

Joint Arizona Consortium - Manufacturing and Engineering Education for Tomorrow

In partnership with universities and industries in Arizona, RMSC set up a program that provides post-graduate level education for engineers, and involves new approaches to updating the manufacturing/engineering workforce. Since conventional graduate/undergraduate curriculum programs fall short of meeting advanced-level manufacturing/engineering educational needs, the consortium established its own innovative training program. Members of the consortium include Arizona State University, Northern Arizona University, University of Arizona, Allied Signal, Boeing, IBM, Motorola, and RMSC.

Known as the Joint Arizona Consortium - Manufacturing and Engineering Education for Tomorrow (JACME^{2}T), this program provides an excellent model for collaboration between industry and universities, and offers career-long, professional learning for graduate engineers and technical professionals who work in

manufacturing and product development. JACME²T's courses use innovative and pertinent methods of delivery, making them affordable and accessible. In addition, the program encourages participants to take charge of their own ongoing education. Industry engineers are directly involved in curriculum development as well as program instruction. Some of JACME²T's courses are designed to prepare practicing engineers for career redirection, caused by defense conversion and corporate downsizing.

JACME²T uses a novel, educational design approach to develop a set of curricular modules, which focus on the educational needs of industry and have sufficient academic character to earn graduate credit, if desired. A module consists of a set of related, educational experiences that may include graduate courses. Individuals who complete modules are awarded certificates that can be applied toward graduate degrees or can stand alone as recognition of significant educational achievement. The modules are organized around particular industry-driven needs for specialized, advanced training in specific technical areas. Typical courses include JMP Fundamentals; Strategic Product Development; Integrated Product and Process Development (IPPD) Project Management; Object Oriented Analysis; C++ Language Fundamentals; and Rapid Prototyping.

The consortium's organizational structure and methods of operation are designed to bridge the cultures of the academic and industrial communities. A policy board, comprised of executives from each of the participating companies and the deans of the universities, directs the organization. An industry technical advisory board helps define the training needs and delivery approaches. Industry and academic members work together to develop marketing strategies and delivery systems, and to form learning and competency teams. Currently, there are seven learning and competency teams: Design; Environmental; IPPD; Manufacturing Processes; Software; Instrumentation and Testing; and Continuous Improvement.

Major accomplishments of the JACME²T consortium include shared courses with Arizona State University and University of Arizona, a statewide Master of Science program, one-credit modules, certificate programs, and the delivery of courses/programs over the Internet. To date, 116 courses have been offered, and nearly 2,000 students have participated. This program is a true collaborative partnership between industry and academia, which can serve as a nationwide model. Methods are being developed to extend the impact of JACME²T nationally, through various electronic networks, companies, and organizations, as well as an outreach effort for small- and medium-sized businesses.

Knowledge Center Southwest

The Knowledge Center Southwest (KCSW) is a unique, one-stop resource designed to provide a collection of powerful knowledge-based tools that aid employees and teams in their quest to achieve total customer satisfaction. Many of RMSC's top processes are outgrowths of this resource, and represent keys to future performance at the Tucson facility.

RMSC developed KCSW as a way to improve cross-functional team integration and communication. Based on General Motor's Knowledge Center, KCSW was tailored to the missile systems development and manufacturing industry. At the core of KCSW are four tenets of operation, which represent the foundation for successfully deploying improvement tools and processes. These tenets are:

- Structured Methodology — An organized, proven approach to systems development that can be applied to all product lines.
- Common Tools and Processes — Core tools which provide a common framework for benchmarking and evaluating performance.
- Agile Creative Environment — A flexible environment that provides the atmosphere, resources, and information needed to maximize innovation and creativity.
- Rapid Learning — A repeatable cycle for obtaining feedback, making improvements, and creating a consistent, successful process.

As a multi-functional center, KCSW supports teaming facilities; provides product and hardware displays; maintains a tool and process library; features workshops (e.g., six sigma, QFD, design to cost); offers job-in-line training; and operates as the JACME²T office. One of KCSW's most significant capabilities is process tailoring. Here, KCSW provides a system for tailoring enterprise-common processes for specific program and product applications, such as integrated process architecture, new business capture, product development, and program management.

RMSC relied on KCSW models during the proposal phase for its AIM-9X program. In this situation, the agile initiative helped move inventory turns from five to 14, while the six sigma initiative reduced defects by approximately 50%. By providing the proper environment and resources to foster agile designs and manufacturing processes, KCSW plays an important role in RMSC's quest to achieve total customer satisfaction.

Leadership Structure

In the past, RMSC (formerly Hughes) was managed by a stovepipe structure which typically focused on major programs or products. However, this approach did not promote communication between programs, and often prevented savings from being gained via common processes and shared support services. Prior to the Raytheon/Hughes merger in 1997, the company implemented an innovative organizational structure that provided an effective way to manage 9,000 employees, three million square feet of facilities, and more than a dozen product lines. This structure successfully carried the company through the merger, and has led the ensuing changes and improvements that the company has experienced in the past two years.

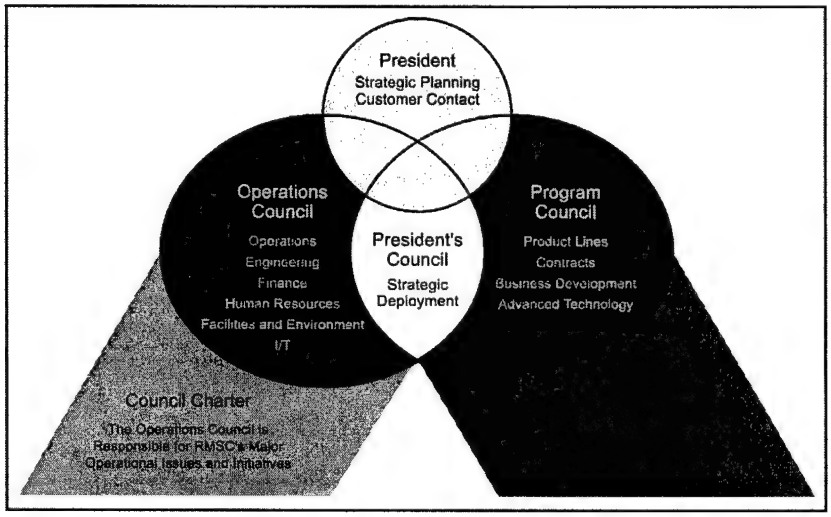


Figure 2-8. Leadership Team

Figure 2-8 shows how the RMSC leadership team is structured. The president's primary role is to oversee strategic planning for the enterprise, and be the primary focal point for customer contact. The leadership team is divided into two councils: the Operations Council and the Program Council. These councils are strategically focused and share the responsibility to guide RMSC, under the direction of the president, toward its vision and goals. The Operations Council focuses on internal customers, guides the support processes, and is responsible for overseeing improvement initiatives (e.g., Vision 2000 implementation teams, six sigma, ISO-9000, agile enterprise initiative, people development). Other responsibilities include employee training, facilities improvements, and computer infrastructure. The Program Council focuses on external customers by monitoring customer relations, business opportunities, global markets, product deliveries, and field reports. Weekly council meetings provide a forum to share information and determine actions among product line leaders. Actions assigned at the council meetings are flowed down to the responsible organizations within the company.

RMSC's leadership structure provided the framework for the rapid integration of cultures and businesses during the merger period, while successfully implementing major improvement initiatives. The council structure facilitates communication, and ensures that the enterprise can leverage off best practices originated in all areas. This management structure enables RMSC to implement integrated process architecture; leverage procurement through purchases shared across programs and business units; and share lessons learned to improve productivity and profits. The Council management structure also minimizes the stovepipe ideology, and eliminates waste associated with running separate businesses within a single, large company.

Lean Aerospace Initiative

The Lean Aerospace Initiative (LAI) was developed in 1993 to enhance the implementation of lean manufacturing practices and principles into the defense and aerospace industries. This consortium is sponsored by the Air Force and administered by the Massachusetts Institute of Technology with 18 member companies. LAI's mission is to define roadmaps for fundamental change based on lean practices. RMSC (formerly Hughes) has supported LAI since its inception, and been one of the principal developers and implementers of lean processes and methods.

The LAI consortium developed the Lean Enterprise Model (LEM) which characterizes the practices and principles necessary for a lean enterprise. LAI uses four task groups which focus on factory operations; product development; supplier relations; and policy and external environment. The consortium also facilitates benchmarking with member companies, and encourages enterprise-wide systematic change. LAI's vision is to significantly reduce the cost and cycle time for military aerospace products throughout the value chain, while continuing to improve product performance.

The implementation of the overarching principles and supporting practices of the lean manufacturing concept provides a well-documented database of proven lean practices that enhance the elimination of waste from enterprise operations. The result is products with higher quality, lower costs, and improved schedules. RMSC adopted all of the overarching lean principles, and enacted programs and practices which implemented lean operations in all its factories and centers of business. Since 1996, RMSC has been testing the LEM as new versions are released. The company is using the lean philosophies and guiding principles, and obtaining the results described in the LEM data sheets and metrics. RMSC is changing its culture to make lean principles an integral part of its day-to-day business and, in the process, is improving customer satisfaction, cost, and quality. Figure 2-9 depicts the relationship between the LEM and RMSC's strategies.

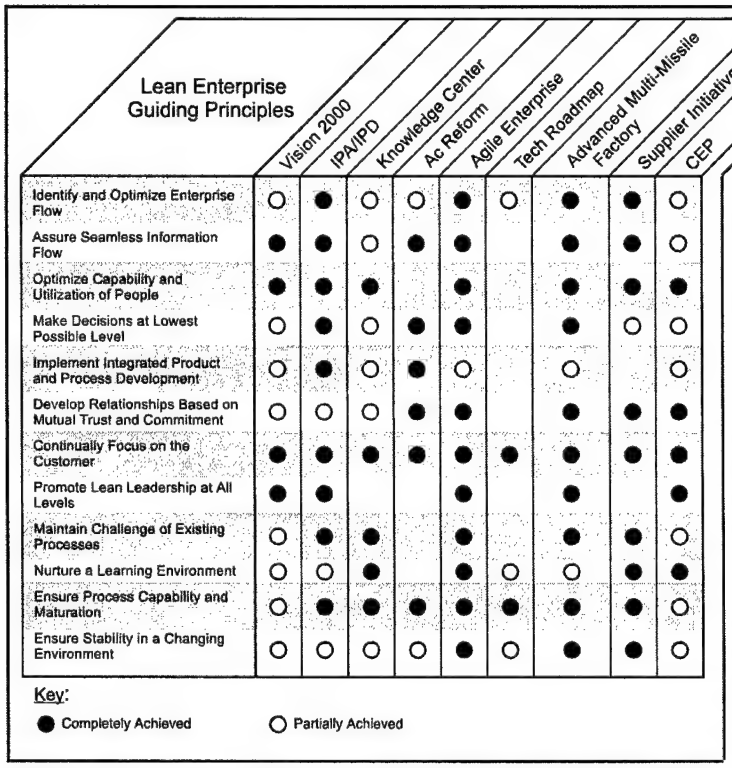


Figure 2-9. Lean Enterprise Model Comparison to Major RMSC Strategies

Participation in the LAI consortium has been a win-win situation for all members. The consortium leverages knowledge development and application in less time and for less cost, as well as broadens the understanding of lean opportunities across the value chain and the enterprise. LAI operates as a source for benchmarking with other aerospace firms and as a method for verifying lean practices and metrics. By using this approach to understand and leverage lean practices and to implement those practices into the enterprise, RMSC eliminated significant waste from its enterprise processes. A consortia approach also provides a direct understanding of a major customer's (e.g., Air Force) expectations.

Manufacturing Methods Plan

In the past, MIL-STD-1528A required companies to develop documentation which illustrated their production capabilities to customers. Like others, RMSC invested significant time and resources to meet this requirement. The company averaged 20 months to develop an initial plan, and an additional 200 hours per year for updates. Because the plan was done at least six months prior to the actual manufacturing, most of the information consisted of best guesses and estimates. With the elimination of this military standard, RMSC no longer needed to submit a manufacturing methods plan as part of its proposal. This change, coupled with an enterprise shift toward agile manufacturing and the development of Centers of Excellence, served as a catalyst for the development of a generic manufacturing plan at RMSC.

To accomplish this task, RMSC began by documenting all of the processes and controls used throughout the company. The company designed its Manufacturing Methods plan as an efficient way to demonstrate production readiness by focusing on the actual manufacturing processes rather than on program specific data or process outputs. This eliminates the need to recreate the document since it is applicable to all programs, and satisfies customer inquiries on production capability. RMSC has also facilitated the plan's use throughout the company by making it easily accessible via RMSC's network.

Since 1996, the Manufacturing Methods plan has been included in every renewal contract at RMSC. As a result, the company reduced its production readiness documentation from hundreds of pages per program to a standardized 35-page document applicable

to all programs. The company also achieved more than $300,000 in cost savings on current contracts, and anticipates continual savings of over $100,000 annually. The Manufacturing Methods plan has been accepted by most production programs within RMSC, and is credited with providing internal and external customers with a better understanding of RMSC's production processes.

President's Communication Forum

Communication within an organization is an essential element of any business. However, this task can be difficult in today's world of mergers and consolidations where employees from different companies and cultures are brought together. Employees need constant reinforcement and feedback from the top down on the status of the company's goals, and on their role within the company's structure. Prompt and effective internal communication enables the company to keep its workforce informed, and allows the employee to truly engage in the business and success of the company. In January 1996, RMSC developed the President's Communication Forum as a vehicle for doing this.

The President's Communication Forum works as a top down and a bottom up communication process. The president conducts comprehensive quarterly briefings to all managers and supervisors who, in turn, cascade the information to their employees by using copies of the presentation material along with a video tape of the president. This approach ensures the accuracy and promptness of the information. At the secondary briefings, employees discuss the information and provide feedback up the chain of communication. RMSC also conducts surveys to verify that the employees are receiving the information and to solicit ideas for improving the process.

The President's Communication Forum is a unique and effective way to communicate within the organization. The forum provides an in-depth account of progress, issues, and metrics at RMSC including organizational changes of the company, market shares and forecast, customer satisfaction, competitiveness, factory performance, quality, people development, union and management partnerships, and financial performance. By being informed through this vehicle, employees and groups can adjust their activities to meet current challenges. The President's Communication Forum reinforces the company's values and mission of Vision 2000, and is a key tool for RMSC in building a corporate culture and a common focus.

Process Improvement Program

RMSC established the Process Improvement Program (PIP) as a way to work with its suppliers to improve their quality, service, and price. PIP operates as a three-day training workshop which is held at the supplier's facility. At these workshops, cross-functional supplier/customer teams examine a current process; identify waste and non-value added activities; and develop plans to implement improvements. A follow-on review is also conducted 90 days after the workshop is completed. This review verifies that the team completed the action items and implemented the planned improvements.

The primary goals of the workshop are knowledge transfer; redefining an existing process; utilizing the expertise of team members; implementing process improvement changes; identifying future areas for process improvement; and demonstrating the magnitude of improvement potential. PIP can be applied to any area that uses repetitive, sequential processes such as in manufacturing, shipping and receiving, shop order processing, and administrative tasks. Lean manufacturing principles are then used to streamline and improve the process under consideration. PIP's key factors to success include total commitment by top management; empowerment of the workshop team; workshop team composition; workshop preparations; and appointment of a supplier champion who is responsible for implementing the improvements.

To date, RMSC has conducted more than 150 workshops in the last 24 months. The company has received many letters of thanks from the suppliers that participated in the workshops. PIP is also endorsed and promoted by the chairman of the company. Since implementing PIP, RMSC reduced inventory by 50%, lead time by 49%, square footage by 28%, and distance traveled by 59%. The company also improved productivity by 40%.

Product Data Management/Product Information Management System

RMSC set up the Product Data Management/Product Information Management (PDM/PIM) system as a direct consequence of IPD methodologies. The company's recent mergers with Hughes, E-Systems, and Texas Instruments underscored the necessity to share data across multiple sites and to eliminate duplicated efforts. RMSC used an IPT to address specific concerns with the former data management system. Reasons to implement a new system included

increased complexity of products; communication among diverse organizations; teaming and partnering over great distances; and integration of legacy system data.

The PDM/PIM system is a powerful tool for streamlining product development by managing data pertaining to design, development, configuration, change notification, and support functions. The system is based on Sherpa's Integrator software, and supports data input from various commercial software packages (e.g., Pro/Engineer, CATIA). Users can access the PDM/PIM system via a Wide Area Network within RMSC.

Since implementing the PDM/PIM system, RMSC reduced product development time and cost; facilitated IPD teaming; established on-line data retrieval; increased internal and external communications; improved schedule and cycle time tracking; documented standards for ISO-9000; and shifted the focus from managing paper to managing data. The company also reduced cycle times for engineering changes by 21%, manpower for data management by 30%, floor space for data management by 63%, and capital equipment costs by $15,000. By scanning the legacy system data into the PDM/PIM system, RMSC saved $5 million in 1997, and estimates a savings of $28 million annually.

Raytheon Missile Systems Company University

The Raytheon Missile Systems Company University is a virtual learning institution designed to provide high quality, agile training for Raytheon employees. The University is committed to the educational development of the workforce; seeks to involve RMSC's business units/functional organizations in all aspects of the learning process; and models itself on the mission, values, and culture of the overall organization as expressed in Vision 2000.

The Raytheon Missile Systems Company University provides everything that employees need to access and effectively use its resources (e.g., library, catalogues, procedures, forms) from their desk tops. The University is structured like a training delivery network, and uses Process Owner Councils consisting of individuals from all functional areas of the organization. The Process Owner Councils design the content and instructional methods for the courses required by and relevant to their particular functional areas. To broaden its ability to meet customer needs, RMSC also established educational partnerships with numerous colleges and universities (e.g., Pima Community College, University of Arizona, University of Southern California, Arizona State University, Northern Arizona University). These partnerships enable the Raytheon Missile Systems Company University to expand its ability to deliver high quality, need-driven education.

Past educational efforts generally presented courses and training in a predominantly rigid, tightly controlled environment, which often had little direct relationship to or input from its customer base (the functional areas within the Raytheon organization). Under the new paradigm, the virtual university draws the requirements, content, governance, stewardship, and instructors from the functional areas for which the courses are designed and funded.

In addition to exceeding ISO-9000, the Raytheon Missile Systems Company University documented impressive indicators of its success. Metrics for 1997 include:

- 269,619 hours in total training, excluding independent learning greater than 13 hours per employee
- 36 hours of training per employee, on average
- $457,000 saved based on donated time
- $1,000 invested in learning per employee
- $8 million in total cost for training
- $29.60 per hour for training

The Raytheon Missile Systems Company University is a dynamic, cost effective, agile tool that is helping RMSC and its employees meet corporate and individual educational needs.

Risk Management Process

RMSC established the Risk Management process as a proactive method to predict potential problems and risks, and effectively mitigate the risks by controlling the process, developing strategies, and addressing issues early in a program. This process enables RMSC to develop and deliver systems that meet customer requirements on schedule and within budget. Risk management is now a part of the monthly metrics required for all programs per RMSC's IPA. In the past, RMSC used a reactive method, which often led to crisis management and insufficient time to implement the optimum solution.

Risk management begins with a basic process which is tailored to a specific program. The process relies on customer needs, lessons learned, expert opinions, and existing management guidelines to develop a specific risk management plan that retains the essential principles of the standard process. Risks are then identified, analyzed, and prioritized using

various tools to address the differing aspects (e.g., cost and schedule simulations, process analysis, predictive identification). RMSC's main tool is Risk Manager (based on Filemaker Pro with Risk Register and Risk Matrix components) for planning, ranking, and controlling risk. This tool is used to encompass all the risks and criteria found with other commercial and government off-the-shelf risk tools. Prioritization is achieved by determining the probability and consequence of occurrence in order to calculate a risk factor for every identified risk.

Once RMSC prioritizes the program risks, risk reduction begins. The company develops mitigation plans to reduce the risk areas, which are tracked and reported weekly in IPTs and other program events. Risk Manager can output a series of differing reports, including a one-page summary graphic that shows probability of occurrence versus severity of occurrence, and plots the top ten risks as high, medium and low. The Risk Management process continues throughout the life cycle of the program, with ongoing management of risks and identification of new risks being done at each stage of development.

At the start of the ESSM program, RMSC had erroneously estimated that an additional $45 million in funding would be necessary to complete the project. However, after implementing the Risk Management process and having the customer prioritize the requirements, RMSC was able to fulfill the ESSM program without additional funding. Since implementing the Risk Management process, RMSC significantly improved customer satisfaction as reflected in its 85% or higher (outstanding level) award fee rating across all programs. The Navy has also requested RMSC to use Risk Manager plots for all design reviews of the Standard Missile programs.

Rolling Airframe Missile Weapon System

The Rolling Airframe Missile (RAM) is a lightweight, quick-reaction, high-power weapon system designed to provide anti-ship missile defense. The system (Figure 2-10) was co-developed and co-produced under a NATO cooperative program between the U.S. and German governments, their respective national weapon system acquisition oversight organizations, and their respective national industries.

Various agreements govern the RAM program at all levels. At the government level, the program operates under a series of Memoranda of Understanding (MOU). A steering committee, consisting of high-level representatives from each government, is responsible for implementing the MOU. At the industry level,

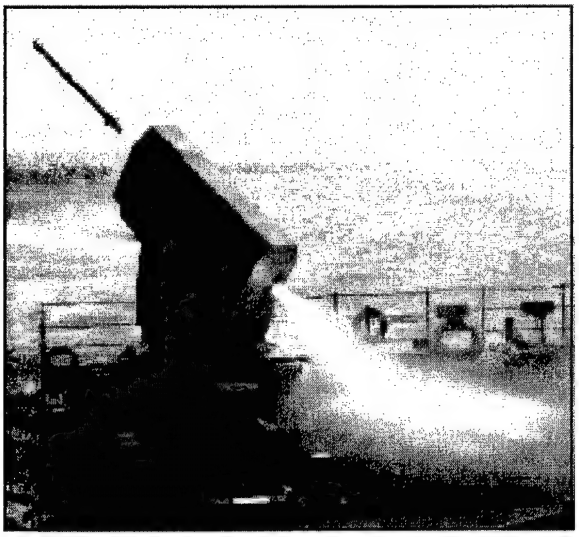


Figure 2-10. Rolling Airframe Missile Launcher

RMSC and RAMSYS (the German consortium of involved companies) work together under a Cooperative Program Agreement (CPA). The actual procurement for the system is run by RAMPO, a joint program office with representatives from each government and their respective defense acquisition oversight organizations. This successful multi-level cooperation between the United States and Germany enabled the RAM program to become a reality.

The CPA between RMSC and RAMSYS is a long-term arrangement that calls for a 50-50 split on all buys, with the procuring government's supplier designated as prime. Key missile technologies are dual sourced, so both national industries retain the ability to integrate the final deliverable. Non-critical items may be sole sourced. Manufacturing integration exists at all assembly levels. Some assemblies are built 100% by one partner, while others are done as a 50-50 venture. Workshare for any required development is proportionate, and an agreement is employed for joint marketing and third-party sales. A common design agent, as well as a common technical data package, are used to resolve production problems and the joint procurement of common parts. Electronic data exchange is key to the successful operation of the entire program.

While the establishment of a joint international program can be complicated and expensive, the advantages are tremendous. Only the successful partnering between the United States and Germany empowered the RAM program's development, since neither country could have justified the independent development, production, and fielding of the system at the expected procurement levels and rates. The joint

program enabled the RAM contracts, implemented under the CPA, to be accomplished on time and within budget, and resulted in the delivery of an effective and affordable weapon system. RAM's effectiveness has been demonstrated by the flight success of 106 hits out of 111 firings since the start of production. In addition, this collaboration has been a model for the 13-country industrial consortium that is producing and deploying the ESSM program.

Sight and Sound Media

RMSC's Sight and Sound Media is a multi-functional media communications facility capable of producing state-of-the art photographic digital imaging and video editing, as well as traditional photographic and video services. Divided into the services of Photo, Video, and Instrumentation, the facility handles all media communication needs for the company, its customers, and the local community. The Sight and Sound Media maintains over 800,000 negatives and 5,000 hours of videos; generates 12,000 new negatives per year; and is capable of high-speed photography up to 40,000 pictures per second.

The Sight and Sound Media combines the best photographic, video, and instrumentation capabilities from five other divisions as a result of the recent mergers and consolidations. Prior to these consolidations, each division offered various degrees of capability in these services. Total staffing was 60 employees. The establishment of the Sight and Sound Media enabled RMSC to reduce the overall staff, and increase its capabilities and services. The facility supports many groups at RMSC, and offers one-stop shopping services in Photo (e.g., product display photos, electronic imaging, formal portraitures), Video (e.g., taping and editing, narration, standards conversion), and Instrumentation (e.g., high-speed photography, field testing, multiple and sequence cameras).

Staffing now consists of five personnel for Photo (e.g., photographers, technicians), seven for Video (e.g., scriptwriter/narrator, electrical engineer, cinematographer), and one for Instrumentation (e.g., instrumentation, videographer). The facility uses automation for inventories, tracking of negatives, videos, instrumentation, and job requests. In addition, the Sight and Sound Media provides unique instrumentation and quick turnaround times which are not readily available by other internal or commercial sources. Almost 50% of the workload comes from the engineering test group, followed by the operations group at 14%.

One of the Sight and Sound Media's unique capabilities enlists the use of sophisticated multi-cameras and instrumentation to obtain video shots of RMSC's missile test launchings. In 1997, the facility spent 4,000 hours in the field conducting these types of services. By combining the best capabilities and personnel skills from the other facilities, the Sight and Sound Media provides extremely effective and centralized communication services for RMSC.

Single Process Initiative

In May 1995, RMSC developed a process to approve and implement block changes for common processes, as directed by the Single Process Initiative (SPI) for acquisition reform. RMSC's SPI approval process relies on technical and cost IPTs. Previously, the company maintained and used multiple processes, regardless of product similarity, to meet each contract's requirements. This approach resulted in duplicated efforts and excess costs.

Each proposed common process is assigned a technical IPT, which is led by RMSC and uses representatives from RMSC and DCMC. The technical IPT fully defines the proposed process by eliminating non-value added components and conflicting program requirements, and ensures that the new process provides equivalent/improved quality compared to current processes. The team submits the proposed common process as an idea paper to DCMC for approval. Once approved, the team is expanded to include the Program Executive Officer, program office, and other applicable government representatives. The revised IPT resolves any technical concerns and obtains customer concurrence.

In concert, a cost IPT determines the cost impact of a proposed change. This team is led by an RMSC estimator, and consists of a technical IPT leader, a technical IPT DCMC representative, and other technical experts, cost analysts, and estimators as needed. The cost IPT identifies the assumptions for assessing the cost impact for current contracts, and for determining the sustaining yearly cost avoidance. After completing the cost impact estimates, RMSC prepares a concept paper for the proposed common process, which details the process, provides associated metrics and consequent changes, and contains a rough order of magnitude cost/benefit analysis. The paper is submitted to the Management Council (with representatives from DCMC, the Defense Contract Audit Agency, RMSC, and key customers) for approval and execution of the block change modification for all U.S. government contracts at the site.

Since RMSC implemented this process, 29 SPIs have been approved and are currently used at RMSC; four are presently in the review process; and many others are being addressed by technical and cost IPTs. RMSC estimates that the annual cost avoidance of the 29 approved SPIs exceeds $6.6 million. In addition, the company enhanced customer relationships via the customer's active IPT participation, strengthened competition, and streamlined acquisition. In March 1997, DOD presented RMSC with the SPI Recognition Award for its successful efforts in implementing common processes.

Strategic Planning War Room

To remain competitive and at the forefront in tactical missile design and production, RMSC recognized that its traditional stovepipe ideology had to be discarded. The company needed to expand its mode of thinking, share ideas, and capitalize on the ever-growing wealth of business opportunity information from such sources as the news media, trade shows, and DOD's Program Objectives Memorandum. As a result, RMSC developed the Strategic Planning War Room, an innovative process for strategic planning at the enterprise, mission, and program levels.

The Strategic Planning War Room integrates product lines, functional organizations, suppliers, and customer groups, as well as develops Technology Roadmaps for future warfare trends, customer needs, and business opportunities. This approach uses a dedicated room where a Program Council of senior managers meet bi-weekly to interact (e.g., share ideas; consider proposals for areas of future focus and business growth; develop strategies for capitalizing on cost-saving opportunities). The Program Council also assesses customer requirements and expectations that are obtained from such sources as published statements, official documents, and occasional customer participation. This information, coupled with data gained from industry experts on commercial technology trends, are used to develop a matrix of possible opportunities for future business in the near-, mid-, and far-terms as well as the domestic and international arenas. The walls of the war room are used to post graphic information for use in developing company strategies. Data and information are arranged in sequential fashion, so that the thought process is lead in a strategic planning direction.

The Strategic Planning War Room successfully breaks down long-standing barriers in communication between programs and functional groups. This approach facilitates the establishment of plans for technology, manufacturing, and personnel development. Analyses of Technology Roadmaps are used to make strategic decisions in various areas including make/buy, core competency retention/development, supplier partnering decisions, and Internal Research and Development. Attesting to its success, this strategic planning methodology and process are being mimicked by several DOD entities.

Supplier Base Participation in Single Process Initiative

RMSC set up the Supplier Base Participation in Single Process Initiative (SPI) to encourage its suppliers to participate in SPI for acquisition reform. This simple, effective process enables suppliers to rapidly obtain approval for supplier SPIs, and immediately implement many of the common processes approved through RMSC's SPI system without further review. Previously, no defined approval process for supplier SPIs and no formal means for suppliers to implement RMSC SPIs existed.

The company set up a Technical Review Board (TRB) to process and approve SPIs from its supplier base. As requests are received from the suppliers, the TRB calls on RMSC technical experts to review each request and provide feedback to the review team. The proposal may also be reviewed by the customer, if the contract requires this action. The TRB either rejects the request or approves it for implementation at the supplier's site. As an additional way to involve suppliers in acquisition reform, RMSC developed and incorporated a standard language for all production orders, which allows many of the approved RMSC common processes to be automatically implemented without further review or notification.

Since being implemented, the Supplier Base Participation in SPI appears to be very promising for approving supplier SPIs and creating flowdown of RMSC SPIs to the supplier level. Currently, five supplier SPIs have been received and approved. The most complicated request incorporated 46 processes, and necessitated a review and approval by 18 RMSC technical experts. This request was processed and approved in ten days. By implementing SPI at the supplier tier, RMSC reduced costs via streamlined acquisition, eliminated duplicated efforts, enhanced prime contractor/supplier relations, and created a rapid approval system.

Supplier Liaison Information Control

The Supplier Liaison Information Control (SLIC) system is an automated tool for collecting critical documentation and information from RMSC field engineers who reside at 17 locations across the United States. Prior to 1996, this process was done manually. Weekly reports, schedules, audit reports, and other documentation were manually filled out on paper forms, mailed to RMSC, logged in, filed, and continuously updated. This activity was augmented by daily telephone calls and faxes between the field engineers and the company to maintain status and direct changes to itineraries.

The SLIC System allows field engineers to remotely access the database at RMSC via laptop computers. The field engineers complete automated electronic forms, and transmit them via modem to the source control office at RMSC. Likewise, changes in schedules and itineraries can be made in real time based on evolving needs of the company. The data received by the source control office is already digital, which allows the information to be easily converted into trend charts and activity graphs.

By implementing the SLIC system, RMSC eliminated paper and labor costs, decreased turnaround time for processing, and gained real-time information. This application provides a strong first step for future improvements including the use of digital cameras and video teleconferencing for real-time, virtual Material Review Board Dispositions — a valuable attribute in a just-in-time environment.

Technology Communication

RMSC recognizes that its future business is critically dependent on the company's ability to develop and maintain superior technical expertise in its workforce. This task requires focusing on technology and the rapid dissemination of technical information throughout various scientific disciplines, programs, RMSC, and the corporation. During the 1993 merger between Hughes (now Raytheon) and General Dynamics, this focus shifted. As a result, training and technical excellence became unprioritized, and competitiveness was reduced. In 1994, RMSC established a goal to develop technical excellence at the design engineer level which led to the enterprise-wide Technology Communication program.

The main focus of this program is increased technical communication within RMSC. The Corporate technology structure facilitates communication by establishing a forum for sharing technical information between individual segments, across business divisions, and throughout the corporation. Bi-annual Independent Research and Development (IRAD) reviews by segment and a company-wide IRAD database also distribute the latest capabilities to a larger audience. Technology networks in specific segments (e.g., electro-optics, radio frequency, signal processing, software, systems, mechanical, materiel) enable information to be shared throughout RMSC via internal and external conferences, workshops, and technical excellence awards. Employees who are unable to attend these functions can obtain a CD-ROM of any seminar or conference. RMSC also conducts periodic informal brown-bag lunch technical exchanges and one-hour technical presentations every Thursday afternoon after work hours. Since 1995, the company has conducted more than 6,000 hours of training.

RMSC encourages external technical communication by automatically paying for conference attendance of employees who present papers or officiate a conference. Engineers are encouraged to accept official positions in technical societies, and RMSC gives out Published Paper and Outstanding Paper of the Year Awards. Internal communication at RMSC is done through a Technical Experts Panel. This panel consists of 35 multi-disciplined engineers and/or scientists, each with more than 15 years of experience. The company provides a budget of eight hours per week per engineer for technical participation in design/program reviews, plans, proposals and tiger teams. Each expert member mentors five junior engineers/scientists. The Technical Experts Panel also develops the IRAD technical strategy, forms the patent committee, and participates on special assignments as needed.

Peer reviews are used to improve communication during the design process, and are a planned part of the program throughout the design cycle. Members of a peer review include the designers, peers from another program, a technical expert, a section manager, and the department manager. The goal is to perform a detailed technical analysis of the design by leveraging on the Corporate technical knowledge. The reviews are included in the company's monthly metrics.

The Technology Communication program makes Corporate technical knowledge available to programs from the earliest stages of design; keeps the workforce technically competent and aware of internal and external developments; decreases the likelihood of design errors; and reduces product development costs. In addition, the program promotes technical communication; fosters technical innovation; and motivates engineers to stay at RMSC. The employee turnover

rate at RMSC is 1.5% to 2%, compared to the industry average of 12%. Technical excellence through communication is a coordinated company strategy, which ensures that the right technology and design approaches are being applied to customers' needs.

Technology Roadmaps

Technology Roadmaps are a key element of RMSC's strategic planning process. This tool identifies technologies that are critical for future customer and product line needs; assesses them in light of predicted industry technology trends; and helps management make decisions regarding IRAD and future business. Declining defense budgets adversely impact the amount of funding which contractors can dedicate to IRAD. This fact, coupled with the quickened pace of technological process and product change (primarily in the commercial world), dictate the need to effectively predict the future direction of technology and customer needs, if companies are to remain competitive and responsive.

The Technology Roadmap process involves a continual examination of the marketplace to forecast which core technologies will be required for next-generation products, and to determine how well RMSC is positioned to capitalize on them compared to the technology capabilities of its competitors. This tool also helps RMSC identify disruptive technologies, which inherently compete and may require hard business choices. For example, should the company pursue charged particle beam technology which would compete with the core missile focus in the anti-ballistic missile arena?

In simple terms, the Technology Roadmap process plots future technologies versus future customer and product line needs. The resulting matrix reveals the areas where the two roadmaps will likely intersect. The results of the Technology Roadmap analysis are then integrated into the make/buy decisions involving retention or development of core competencies as well as those that will be obtained through partnering, mergers or acquisitions.

Totally Integrated Enterprise System

Previously, RMSC's program initial phases were characterized by a series of start and stop activities (e.g., proposal team formulation and disbanding) in which generated project data was ineffectively collected, stored, and made accessible for use in subsequent phases. The result was an expensive, inefficient, start-up process that led to poor contract performance. To resolve this situation, RMSC developed a suite of tools known as the Totally Integrated Enterprise System (TIES).

TIES is designed to facilitate a closed-loop methodology that governs all phases of a program. The system ties together all aspects of engineering and manufacturing programs including initial development of integrated master plans and schedules, proposals, contracts, budgets, executions, and closeouts. By using a closed-loop methodology, TIES enables a program's baseline (created at the bid decision) to be reported, refined, and updated in each subsequent phase. This state-of-the-art system creates a flexible environment that encourages tasks to be automated. Attributes of TIES include a single, shared planning and actuals database; an integrated business process; program cost visibility; a flexible client/server system; and a multi-platform architecture.

RMSC has successfully employed TIES in numerous proposal and support activities. During the first several years of implementation, the company reduced its management information workforce by 33%, decreased cycle time by 52%, and maintained an approximately equivalent workload. TIES represents a pioneering effort in integrating project plans, estimates, budgets, and performance measurements.

Unified Community Advisory Board

Prior to 1995, the community's voice was primarily heard in an adversarial manner through local neighborhood meetings, newspaper articles, and the electronic media. This practice created an atmosphere which destroyed open communications and trust among regulatory agencies, industry, and the community. Media coverage also reflected this mistrust and misunderstanding by reporting negative articles 75% of the time throughout the 1980s. In 1995, RMSC created the Unified Community Advisory Board (UCAB) as a way for the community to express its concerns, values, and opinions in a positive and constructive manner.

UCAB is a unique outreach program which involves and empowers the local community as major stakeholders in environmental decisions. These stakeholders (the general public, community activists, University of Arizona, Tucson International Airport, the Air Force, and RMSC) work together to resolve issues, and participate in the clean-up process at the RMSC plant site, including much of the Tucson International Airport Area Superfund Site. UCAB's value is evident in the stakeholders' synergy and focus on their common goal of environmental restoration. The stakeholders have been instrumental in implementing major environmental initiatives in

record time. The advisory board has significantly reduced the startup times of many projects, often by as much as three years.

Through UCAB, RMSC provides training and awareness sessions at local middle schools, high schools, and colleges. The company is also involved in curricula at two universities and a local community college. The students from these institutions perform fieldwork at RMSC to learn about the company's commitment to environmental stewardship, and to gain valuable first-hand knowledge on Superfund site clean-up efforts.

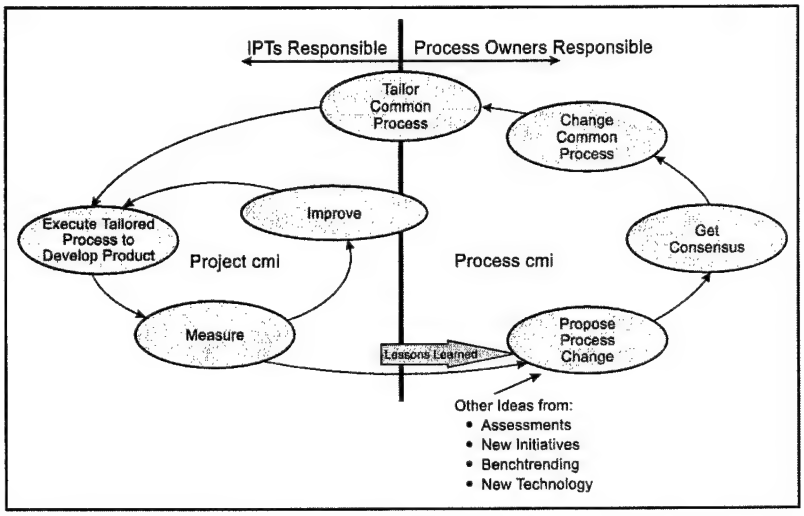


Figure 2-11. Continuous Process Management and Improvement

Since its implementation, UCAB improved communication and trust among the local constituents, and reversed negative reports about RMSC's operations. Consequently, the company enjoys positive media coverage 85% of the time. UCAB also enables regulatory agencies, industry, and the community to openly discuss issues, devise action plans, and make a difference in environmental and clean-up efforts.

Using Metrics to Drive Process and Quality Management

Several years ago, RMSC realized its manufacturing capabilities were not meeting the customer's cost expectations. As a result, the company began efforts to improve its processes, and turned to metrics as a way to drive process and quality management. Initially, process owners and general managers tracked the deployment of engineering disciplines across their programs as a way to increase the awareness and use of process improvement metrics. Now, metrics are required for all programs as a part of RMSC's IPA.

RMSC starts every program with standard IPA processes, and tailors them to individual needs. Laboratory managers review the tailored processes to ensure that critical elements of each process are maintained. The IPT program, responsible for the tailored process, identifies and collects standard and six sigma metrics on the key processes for continuous assessment across various engineering disciplines (Figure 2-11). Standard metrics include cycle time, defect detection, design-to-cost, risk mitigation, design reviews, top production issues, design reuse, staffing, and training. Although all processes do not require a six sigma level, RMSC uses these metrics to identify sources of defects, and to increase producibility, design for manufacturability, and communication among engineering disciplines. This approach reduces cycle time, and improves costs, performance, and schedules for individual programs. Monthly process reviews are used across the enterprise.

In addition, RMSC tailored the Software Engineering Institute's Capability Maturity Model to be applicable to all mechanical, electrical, and software design processes. By identifying the maturity level of a process, RMSC can determine the associated estimates for risk level, producibility, and quality capability. Maturity of processes is another way for the company to benchmark against the rest of industry. RMSC also measures and analyzes in-process defects to identify defect type, occurrence pattern, and trends at the project and organization levels; identifies and resolves systematic problems; and addresses project-specific problems early in the life cycle to reduce rework costs. By using process sigma levels and in-depth understanding, designers can develop new processes and estimate sigmas. Actual sigmas are compared to predicted ones, which enable RMSC to quickly resolve new issues. Although existing programs may not reach the maturity levels of newly planned ones, RMSC's continual use of metrics enables all programs to address process improvement and achieve reduced cycle times and/or defect levels.

Work and Family Strategies Program

The demographics of the U.S. workforce have changed over the last half century. This workforce is no longer a European male-dominated arena, with the male at work and the female at home. As a result, many

companies must now address the impact of family and personal issues on their productivity. The percentage of women in the workforce has doubled since 1950, and the number of single parents has tripled since 1960. As the current workforce ages, elder care is increasingly becoming an issue, much like child care did in the 1960s and 1970s. Today's workforce is also more displaced and mobile than earlier generations. The support system of nearby grandparents and siblings is becoming rare, and the dramatic downsizing of corporate America has diminished company loyalty.

Nowadays, corporations are assuming the role of assistance provider to maintain a stable, motivated, and productive workforce. As a result of mergers, RMSC's Work and Family Strategies program is a compilation of legacy programs from Hughes and General Dynamics. The program provides assistance to the employees on a wide range of issues via family support activities, including:

- Real-time expert assistance in dealing with illness and other emergency situations through an outsource supplier, the Dependent Care Connection (DCC);
- In-home care givers for sick children financed almost entirely by the company;
- Proactive pre-natal care and education;
- Education and consulting assistance for elder care and parenting;
- Company-sponsored family activities;
- Dependent daycare and child care assistance.

Through employee dedication and some outsourcing, RMSC manages this impressive collection of family programs with one in-house coordinator. The returns, however, are impressive. In 1997, DCC counselors handled 952 employee cases with an estimated savings of $337,000 in lost work hours. This savings is several times the total cost of outsourcing to DCC. The Work and Family Strategies program is making a difference in RMSC's workforce. Employees are more productive, less distracted, more loyal to the company, and suffer fewer absences. In addition, this program serves as an incentive to attract new employees as well as retain current ones.

RMSC's all-inclusive program covers every employee situation (e.g., families, singles, income levels). In addition, the Work and Family Strategies program addresses a wide spectrum of family life cycle issues in a real, immediate, and supportive manner. Not surprisingly, RMSC's program has been the recipient of both regional and national recognition for excellence.

Section 3

Information

Design

Design Standards for Pro/Engineer

RMSC implemented standard design modeling practices so that Pro/Engineer modeling software could be effectively used throughout the company. This standardization fosters a "Design Anywhere, Build Anywhere" philosophy. Pro/Engineer is a powerful software package for making 3-D models of parts. Data contained within a Pro/Engineer file can be transferred directly to machining and engineering centers for analysis, using finite element analysis functions. However, the software program requires the use of skilled operators for inputting data. Technicians and engineers must also be consistent in their representation of hardware details. If drawn incorrectly, hardware features can cause defects downstream in manufacturing (e.g., machining operations), despite appearing to be accurate in the graphic file representation. Even the simplest part can be misrepresented if standards are not followed.

Using a Standards Team, RMSC incorporated many standards including Start Files; Standard Configuration Files; Modeling Method Manuals; and a Fastener Library.

The Start Files consist of:

- Start Part — a baseline part creation with standard view and datum definitions, and standard layering convention
- Start Assembly — a baseline assembly creation with standard view and datum definitions, and standard layering convention
- Start Sheet Metal — a baseline manufacturing creation

The Standard Configuration Files consist of:

- Configuration Pro — standard load point configuration options with facility specific options available
- User Configuration Pro — templates with additional configuration options
- Project Configuration Pro — templates with additional project specific configuration options

The Modeling Method Manuals consist of:

- Modeling Methods — a manual describing basic Pro/Engineer functionality for standard modeling procedures
- Advanced Modeling Methods — a manual describing advanced and module-specific functionalities

The Fastener Library consists of data files for 28,000 initial parts such as nuts, pins, screws, and washers. RMSC is currently creating additional data files for connectors, inserts, and rivets.

Key Characteristic Designation System

RMSC implemented the Key Characteristic Designation System (KCDS), which focuses on key product characteristics (KPCs) and attempts to control excessive variation in product features. KPCs are those characteristics for which reasonably anticipated variation can significantly affect a product's safety or fit/function. Excessive variation in product characteristics can also affect a product's compliance with government regulations, or the quality of subsequent manufacturing operations.

RMSC realized that equal attention to all product characteristics does not necessarily yield desired product quality. If strictly enforced controls are used across the board, they can also impact non-critical product characteristics and add to product costs without increasing value. Instead, the company focuses on the critical aspects of a product in an attempt to make larger improvements in product performance and customer satisfaction. By focusing on KPCs, any additional costs to reduce or control manufacturing variation will directly add to the value of the product. KPCs are identified through experience in manufacturing, lessons learned, and the formalized process contained in KCDS.

KCDS helps improve the quality of products during the product design phase, and during the ongoing manufacturing and assembly operations. Throughout these phases of a product's life, this system facilitates improvements in customer satisfaction, communication, efficiency, product design, process design, manufacturing, assembly, and the end product. KCDS also utilizes teamwork, and promotes customer involvement to define and address critical items in a product's design. When used early in the design process, KCDS assures robust designs and limits process variation.

The objective of KCDS is to provide a basis for production process control activities. This goal is accomplished by identifying KPCs; establishing a common language for communicating key characteristics; providing a formalized system for prioritizing product characteristics; and improving products driven by customer satisfaction. Once KPCs are identified, they must be translated into key control characteristics (KCCs). KCCs are the process characteristics which most significantly impact a product's quality and performance. Through a combination of engineering experience and Monte Carlo analysis tools, RMSC determines the cause and effect of product variability, and identifies KCCs for KPCs.

RMSC recently implemented KCDS on the AIM-9X program. Currently, there are 300 unique drawings on the AIM-9X, of which 75% have been reviewed. Of these, less than half have existing KPCs, and those drawings that do, have one to four KPCs per drawing. Results of KCDS's impact on the AIM-9X program are pending.

Russian Electroflotation Technology Partnership

RMSC has formed a promising partnership with the U.S. Air Force and Russia's Mendeleyev University of Chemical Technology. The partnership's objective is to develop a full-scale working model of a Russian-developed and Eastern European-utilized technology for treating complex organic and other synthetic compounds in wastewater. Known as electroflotation, this technology fosters the full reuse of rinsewater; contains less components in the apparatus; and does not generate a secondary wastestream.

As electronic manufacturing operations continue to employ more complex organic and synthetic compounds in their wet processes, more advanced methods are needed to treat wastewater prior to sewer discharge. Electroflotation is a potential next-generation method for treating wastewater from these operations. This method is expected to reduce operational costs, and provide a technological advantage over current procedures.

Electroflotation is the process of generating, via electrolysis, a controlled cloud of charged hydrogen and oxygen gas bubbles, which rise through the wastewater solution and attach themselves to insoluble contaminant particles (e.g., hard-to-treat metals, organic substances). The foamy layer (flotosludge) that gathers at the surface is then skimmed off by mechanical or other means. The concentration of the bubbles can be more than five million per liter, allowing for a high rate of contaminant removal. Electroflotation is cost effective, and ten to 100 times faster than traditional gravitational precipitation methods used for separation.

Electroflotation technology could be a viable solution for treating wastewater containing complex compounds, which can potentially close down production operations. RMSC is currently working with Concurrent Technologies Corporation to promote the use of electroflotation technology in broader applications.

Six Sigma Robust Design Process

RMSC's Product, Process, and Performance Improvement Group has begun implementing six sigma process controls into the company's early design cycles via the Six Sigma Robust Design process. This customer-focused, quality improvement discipline is expected to provide a framework for significantly reducing defects in key products and processes. Nowadays, customers demand higher levels of product performance and quality, at a lower cost, and with greater responsiveness through reduced cycle times and added value. This process will enable RMSC to maintain its focus on these customer demands.

The goal of the Six Sigma Robust Design process is to identify design drivers that have the potential to negatively impact production and cause increased quantities of defects per unit. The process uses a methodology to predict defect rates of new design concepts, and allows design engineers to optimize the design performance prior to manufacturing. Early visibility of product performance, product yields, costs, and cycle times provides design engineers with the necessary information, thus enabling design for manufacturing, cost efficiency, and customer satisfaction. The six steps to six sigma are: identify requirements; identify critical characteristics of the product; identify the sources of variability that affect quality; establish targets and tolerances; assess first-time yield; and adjust designs and processes to meet sigma targets. These steps help the user predict process performance during all product development phases.

The Six Sigma Robust Design process also uses the SigmaCard Scorecard to provide an opportunity-and-defect-per-unit overview of a program, and the Process Capability Analysis Tool (PCAT) Set to model a process, based on cost, from a process perspective. Recent, robust-design, success stories (utilizing PCAT Set) addressed a reduction in defects per million opportunities. The result was $48.3 million in cost avoidance for RMSC's missile programs.

Team of Teams

The shrinking marketplace for military parts has begun impacting military contractors. As a result, contractors must turn to commercial parts to repair military products and/or continue production operations. The challenge is to accomplish this task without impacting the reliability or performance of military hardware. In January 1998, RMSC implemented the Team of Teams approach to address issues that affect various Raytheon divisions. This approach uses multi-functional teams of experts from across RMSC.

RMSC used the Team of Teams approach to adapt commercial practices for designing and building military hardware with commercial components. First, the multi-functional teams identify those areas of the infrastructure being affected. For each area, a team reviews the existing knowledge and defines the common processes. These efforts are then integrated by higher-level teams to provide a coherent result. The key to the Team of Teams approach is to share common information throughout the company, thereby obtaining possible solutions and a final integrated result. The success of implementing commercial parts into Raytheon operations depends on the company's ability to make all affected areas competent in the new process.

The Team of Teams approach promotes communications within the company, and provides access to a historically, untapped network of knowledge and leveraged resources. The continual interaction of these teams also leads to integrated processes that work coherently to produce a reliable product. Another example of the Team of Teams approach is the Raytheon Electronic Packaging Consortium, which is working together to solve electronic packaging issues.

Production

Accident Boards and Fairs

RMSC developed several EH&S programs designed to increase employee and management awareness. Two of these programs are the Lost Time Accident Board, and the EH&S Fair.

The Lost Time Accident Board is a large sign placed at all main entrances into RMSC. This sign displays a permanent safety slogan; the running total of days without a lost time accident; and the previous best record. RMSC established the Lost Time Accident Board as a way to lower accident rates and meet company goals by making employees aware of these accidents and encouraging them to become enthusiastic about beating the previous record.

The EH&S Fair, held once a year, showcases approximately 60 environmental and safety exhibitors from the local community (e.g., EH&S-related corporations, law enforcement agencies, health care providers). The exhibitors set up booths at RMSC, and employees have an opportunity to visit the displays during their lunch hour. The EH&S Fair features demonstrations, educational information, and new safety products for the home, work, and recreational environments. The objective is for employees to work and play more efficiently and safely. These EH&S Fairs are also conducted at local schools to educate middle and elementary students about home safety.

The Lost Time Accident Boards and the EH&S Fairs place awareness and safety data at the forefront to educating employees. In addition, these programs demonstrate RMSC's commitment to safety, and reinforce EH&S as an important part of life.

Best Value Analysis for Procurement

In the past, RMSC chose vendors primarily by low bid or through qualitative knowledge of individual buyers. Although quality and delivery data was available, the method for retrieving this information was difficult and time consuming. In 1991, RMSC implemented Best Value Analysis for Procurement to simplify and validate its vendor selection process.

Best Value Analysis for Procurement provides historical data from the Supplier Performance Rating System, which is accessible by commodity, part number, or vendor. This automated tool also quantifies additional costs caused by a vendor's late deliveries or poor quality products. Documented data (e.g., late delivery information, non-conforming material documents) is entered into the system, and maintained by specific vendor for a rolling period of 24 months.

Using standard algorithms, Best Value Analysis for Procurement automatically considers past performance and assigns a cost adjustment factor, or Performance Index (PI), to each vendor. The PI is then multiplied by the potential vendor's bid price to obtain an anticipated best value cost of buying a specific part from that vendor. For example, a vendor with a good quality and delivery history for a specific part/commodity would have a PI of 1.0, and the projected cost of doing business would be the bid price. A vendor with a poor quality and/or delivery history would have a PI greater than 1.0, which would make the anticipated cost of selection higher than the bid price. Readily available, this information helps the buyer make a best value decision based on quantitative historical data. In cases where the best value

vendor may not be appropriate, the buyer must provide documented rationale (e.g., complexity or technical adequacy of the product) in order to select someone else.

Best Value Analysis for Procurement enables RMSC to determine the best value vendor for each purchase. The primary strengths of this tool include providing instant, accessible historical data, and quantifying the anticipated costs of doing business with competing subcontractors. As a result, RMSC can make timely and cost-effective purchasing decisions.

Certified Supplier Program

In 1991, RMSC initiated the Certified Supplier program to reduce the costs and cycle times of its receiving and inspection processes. The program also addressed costs associated with travel, source inspectors, duplicate receiving inspections, and non-conforming material/corrective action activities. This quality rating system bases supplier certification on historical data such as demonstrated superior quality performance, and confidence levels that the supplier will continue at the same high level of performance.

In February 1998, RMSC improved its program by adding supplier certification for low technology parts as well as part number certification for high technology parts (previously defined as Group 1 parts by MIL-STD-1535). Many factors must be considered before a supplier/part candidate can be approved including supplier management and procurement experience; lot acceptance rate; floor failure data; and stakeholder experience (e.g., supplier quality, procurement and production engineering).

The Certified Supplier program also motivates suppliers to maintain or improve their quality performances. Purchase orders are awarded to those suppliers that demonstrate a long-term commitment to superior performance. The program currently includes 440 suppliers and 16,000 part numbers, which represent about 26% of procured parts. Since 1991, the company reduced the number of receiving inspectors from 18 to two. Annual goals for increasing the number of certified suppliers are established as quality initiatives. Source and receiving inspection factory data indicates a downward trend in defects over the last three years.

Since implementing the Certified Supplier program, RMSC reduced the total ownership cost of procured products, eliminated duplicate receiving inspections, and decreased cycle times. The program also supports agile manufacturing practices by letting certified suppliers ship directly to stock.

Corrective and Preventive Action Teams

Per MIL-STD-1520 (Corrective Action and Disposition System for Non-Conforming Material), all major DOD weapon systems contractors were required to control non-conformances; determine the cause and necessary corrective action in such instances; and setup Corrective Action Boards (CABs) to assure the effectiveness of corrective action efforts. This military specification was canceled as part of DOD's initiative for acquisition reform, which emphasizes increased reliance on commercial and performance requirements rather than military requirements. In response to this action, RMSC established Corrective and Preventive Action Teams (CPATs) to proactively address methods for reducing non-conformances. Similar in makeup to CABs, CPATs consist of engineering, quality, and production managers.

In January 1998, RMSC initiated a company quality policy calling for all missile factories to transition from CABs to CPATs, so that the focus would be on preventive and corrective actions. This policy is in consonance with agile manufacturing efforts used to eliminate waste and improve efficiencies. CPATs meet at least once a month, and address the trends and goals that are identified by individual IPTs of missile programs. Issues are categorized as process, product, or quality. Next, CPATs issue Corrective and Preventive Action reports to IPTs for analysis and improvement actions. This early focus on trends and quality provides a more proactive way to improve quality at an earlier stage than previously possible. IPTs then report back to the CPATs on the results of investigations and planned preventive actions. Reports from CPAT meetings are also forwarded to company management to heighten awareness and promote communications among the missile production lines.

CPATs enable RMSC to support information technology and agile manufacturing initiatives. By implementing these teams, the company fosters a proactive means to eliminate potential causes of non-conformances, reduce cost drivers, decrease manufacturing cycle times, and pursue waste reduction. Trends and goals relating to scrap, rework, defects per million opportunities, and test yield are also reviewed by management on a regular basis.

Cycle Inventory

Per Federal Acquisition Regulation, Part 45, RMSC needed to establish a means of controlling and verifying inventory accuracy levels, as described in DOD's Material Management Accounting Standards. In 1987, RMSC

initiated the Cycle Inventory process to comply with this regulation and provide scheduling accuracy for production. Prior to this system, the company experienced significant problems with material availability.

The Cycle Inventory process is a physical inspection method to validate the availability of parts based on counts taken. An automated data system identifies the inspection levels and sample sizes of parts due for cycle inspection. The most expensive 5% of parts in inventory are verified four times a year. Less expensive parts are verified based on either a twice-a-year schedule or a random 7% yearly sample schedule. Once identified, cycle inspections are conducted on the distributed storage areas (supermarkets), and the results are entered into the system. RMSC's current accuracy rating is 99.2%, compared to its 1987 (pre-implementation) rating of 85%. The Material Management Accounting Standards calls for an inventory accuracy rating of 95%, while the accuracy for government furnished property is 99.9%.

RMSC's Cycle Inventory process provides a systematic view of inventory balances; a visible way to track the performances of supermarkets and specific production projects; and a support system to improve internal production efficiencies. An added benefit is the early warning feature for identifying potential material shortages due to inaccurate inventory data. Since implementing the Cycle Inventory process, RMSC has exceeded its customers' requirements for controlling inventory.

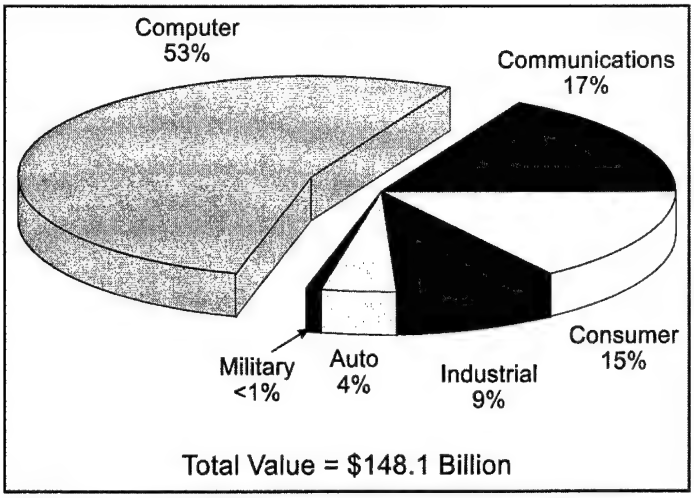


Figure 3-1. Total Worldwide Semiconductor Usage (1996)

Diminishing Manufacturing Sources Management

Like other military contractors, RMSC is faced with the ongoing problem of electronic component obsolescence. This issue is occurring because the number of military systems in operation is decreasing. In today's market, the military represents less than 1% of the semiconductor market (Figure 3-1). The life cycle of technologies used in design, production, and spare support is also rapidly shrinking. Nowadays, the semiconductor market focuses on businesses that procure electronic components in large quantities, leaving small consumers to fend for themselves. To address this problem, RMSC developed a Diminishing Manufacturing Sources (DMS) management strategy to evaluate other avenues for dealing with component obsolescence.

RMSC's DMS management strategy is similar to other programs within industry. First, the company monitors the discontinuance notices forwarded by component manufacturers, industry trend analysis, and aftermarket suppliers to determine what might be available as a replacement. Next, this information is entered into a database for tracking long- and short-term affected applications. Finally, the health assessment of other programs and products is reviewed to forecast system life support requirements. The primary driver for establishing this database is to fulfill the program requirements of low cost/quality resolutions, which is the only acceptable end-line resolution for DMS issues. Often, this fulfillment is done by using alternate part selections, end-of-life buys, Generalized Emulation of Microcircuits, or aftermarket sources.

Although RMSC is striving to stay within the boundaries of the program requirements, the company faces an ever-increasing resistive force of supply and demand, induced by larger market forces. COTS and PEM products offer functional replacements in many cases, but their life cycles cannot satisfy the long-term production requirements. COTS and PEM components typically have a life cycle of 18 months compared to the military-grade component life cycle of seven to ten years. With these replacements, designs cannot mature to production prior to components becoming obsolete in the market.

RMSC is not alone in its search for a permanent solution to the electronic component obsolescence issue facing military contractors. For now, the DMS management strategy is a temporary answer.

Electronic Soldering

Since acquisition reform became a DOD initiative, soldering at RMSC has changed a great deal. At one time, engineers had to be familiar with 35 different soldering specifications, each with their own set of exceptions, in order to judge solder joint quality. A lot of time was spent on making the joints look right. Today, RMSC's Electronic Soldering process is an advanced technology that produces highly reliable solder joints, and uses well-defined requirements, guidelines, and specifications; state-of-the-art equipment; specific materials; controlled processes; excellent skills training; and organized contractor flowdown.

ANSI/J-STD-001, Class 3 is the industry soldering standard used throughout the United States. RMSC's soldering techniques were developed as well-defined processes, based on ANSI/J-STD-001 and the company's ISO-9001 practices. Among the company's capabilities are wave soldering, screen-printing, pick-and-place, reflow soldering, and cleaning. Tools, such as PROCAS, foster the understanding of critical processes, and provide effective customer communication and involvement, teaming, and metrics. Statistical process control is used for conveyor speeds, board preheat temperatures, solder heights, defect data trends, and reflow profiles. Training is done every 18 months, and emphasizes the workmanship associated with actual products. Experienced instructors also develop specific training programs around flex harnesses, chip soldering, tack soldering, and other product-related requirements.

The Electronic Soldering process has been recognized by RMSC customers as an effective solder assembly technique, featuring standard tools and processes. Through its effective skills training, RMSC ensures the transfer of knowledge among employees. Since implementing the Electronic Soldering process, RMSC produces highly reliable solder connections, and improved its competitive edge.

Elimination of Government Source Inspections

The Single Process Initiative is a partnership between RMSC and the U.S. Government. The objective is to identify processes which, when redesigned, will provide added cost savings for the customer and contractor, without compromising product quality. The RMSC/government team addressed two issues: the elimination of Government Source Inspections (GSIs), and the elimination of government signatures on ammunition data cards.

The elimination of GSIs was accomplished in two segments. Based on RMSC's process, the team conducted in-process verifications at the suppliers' sites, and implemented source verification plans using a RMSC source inspector. This plan focuses on using a contractor source inspector to monitor a supplier's processes during the build-up of a product, rather than inspecting the end item. In all cases, the team converted GSIs to Government Source Surveillances (GSSs). A GSS program was established at each supplier's site, and local government representatives would visit to verify the contractor source inspector's findings. In addition, new purchase orders were converted from GSI to GSS.

The second segment involved eliminating GSS, wherever possible, since this process was redundant to the contractor's verification process. The RMSC/government team established low, medium, and high risk categories for parts, based on RMSC's supplier performance data and on input from the Government Product Support teams. The GSS requirement for low risk parts was removed from purchase orders, and the delegation to government field representatives was either eliminated or altered. As a result, the government office at RMSC estimates an annual reduction of 5,000 work hours. In addition, RMSC developed a monthly report for the Government Product Support teams which highlights the quality performance of all sourced parts. Based on this report as well as their own informational sources, the Government Product Support teams can add or delete GSI delegations.

Ammunition data cards are required to accompany all explosive materials during their transport along public routes. In addition, government representatives must sign the data cards to verify the accuracy of the information. The RMSC/government team addressed the elimination of government signatures on ammunition data cards by gathering information on explosive components, including material composition and material lot traceability for safety purposes. In a move to reduce government oversight costs, the Deputy Chief of Staff for Ammunition Procurement issued a waiver which allowed government signatures to be replaced with the subcontractor's (specifically the quality manager's) signature. This waiver affects approximately 400 part numbers.

Through its partnership, the RMSC/government team has helped reduce or eliminate government oversight costs. These efforts decrease contractor costs, leverage existing contractor processes, and maintain the integrity of products.

Industrial Engineering Group

In the past, RMSC's Industrial Engineering group manually reviewed all aspects of the company's production operations, per military specifications. Today, this group uses the latest software packages (e.g., ProModel, Microstation 95, EASE) to optimize production areas, reduce implementation risks, develop labor standards, and perform facilities engineering at RMSC as well as at suppliers' sites.

The Industrial Engineering group's systematic approach examines all aspects of production, and identifies possible impacts. Strategic subcontractor proposals are reviewed and analyzed for direct labor hour usage; material requirements; manufacturing flow; equipment utilization and needs; production cycle times; and labor standards and variances. Products are evaluated for producibility, cost of quality, cost of managing, manpower planning, and resource utilization. The group can also perform product improvement studies, make/buy decisions, bottleneck analysis, and labor efficiency studies. The objective of these reviews is to support negotiated reductions in pricing, benchmark supplier costs for continuous improvement, and help the supplier make a more efficiently built product.

The group also developed a labor standards system by establishing standardized processes and tools for standards generation, application, and estimation techniques. This company-wide system enables industrial engineers to quickly perform standards development and applications; maintain and improve their accuracy; and improve consistencies across RMSC. In addition, the Industrial Engineering group created a common database, and reduced method errors, electronic storage space, and cycle times.

Manufacturing Verification Program

RMSC recognized that quality accountability lies with the individual technicians who perform the work. In 1993, the company developed the Manufacturing Verification Program (MVP) to assure continuous improvement in the quality of its products and processes. Through this certification program, technicians are trained to manufacture and inspect their work. This approach eliminates secondary inspector verification, and places the responsibility for work compliance with the employee. The program is tailored to specific production areas.

Supervisors nominate MVP candidates based on their work qualifications and experience. The candidates receive eighteen hours of classroom training, followed by on-the-job training in operations and inspection procedures. After completing this training, candidates then submit three to five defect-free, final pieces for audit by a quality inspector and subject matter expert. Those who pass the audit become certified for a specific operation and part. Supervisors maintain a skills matrix on each employee. To become an MVP technician, employees must complete this certification process for every operation and item for which they are responsible. MVP technicians are subjected to random sample inspections every two to three months. These technicians can also reject any hardware that they believe is not in compliance with technical data package requirements.

MVP has helped RMSC develop a flexible, mobile, and knowledgeable workforce. Since implementing the program, RMSC reduced manufacturing cycle times; in-process inspections; and overall costs associated with build times, failures, and reworks. MVP also promotes ownership of products as well as empowerment and team development in the workforce. Between 1995 and 1998, RMSC realized a $200,000 reduction in scrap/line loss, which the company partially attributes to MVP's success.

Point-of-Use Material Issue

The sheer volume of parts needed to keep up with assembly line demands (25 units per day) of the TOW missile program, makes kitting an impossible task. In the early days of the program, RMSC used a central conveyor belt, which ran through the assembly area and delivered material. Today, the company uses a more efficient point-of-use method to accomplish this task.

The Point-of-Use Material Issue process moves material from the stockroom to the appropriate location on the TOW assembly line, without first kitting the parts. Mobile carts are used to transport and house material needed at each operation or cell. Material is then fed to each cell from the previous cell. When a cell runs out of items, additional material is sent to that location.

The Point-of-Use Material Issue process enabled RMSC to reduce the cycle times for the TOW missile program by eliminating non-value added time for kitting as well as unnecessary material movement. This process is also an example of RMSC's Agile Improvement practices, which strive to eliminate waste and reduce manufacturing lead times.

Research and Development Partnership

Over the years, RMSC's existing method for removing TCE from groundwater began leveling off due to high-permeability gravel layers; low-permeability clay layers; and the subsurface heterogeneity of water flow. In 1994, RMSC and the University of Arizona formed a partnership (funded through the Air Force) to identify solutions to this situation. Specifically, the group examined the controlling factors for removing contaminants in high concentration areas, and evaluated alternatives to enhance the efficiency of the existing pump and treat groundwater remediation systems.

The University of Arizona's Site Characterization and Systems Optimization project was set up to gather information related to TCE's behavior in groundwater and soil. By understanding this behavior, the group can improve the effectiveness of remediation, and increase the clean-up efforts at the contaminated AFP44 site. This project utilizes several components (e.g., laboratory studies, computer modeling, field tracer studies), which are designed to characterize how water and TCE travel through the aquifer.

The project's ongoing work includes the design, testing, and pilot-scale implementation of two vertical circulation wells (Figure 3-2). To enhance these wells, cyclodextrin (sugar molecules) will be added to the influent as a way to attract TCE to the effluent. This cyclodextrin injection technology (similar to co-solvent technology) is a proven, but not currently practiced method. New technologies, like this, help reduce life cycle costs and improve the effectiveness of remediation efforts at RMSC and similar sites.

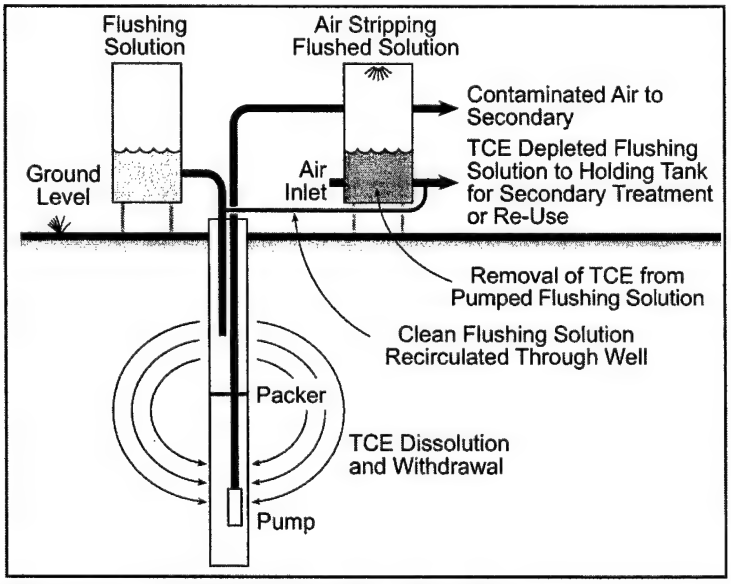


Figure 3-2. Enhanced Vertical Flushing

Besides identifying the cyclodextrin injection technology, the group created extensive 3-D models of the plume. The groundwater remediation 3-D modeling program, developed by the University of Arizona, is an advanced software program which allows the user to manipulate many variables such as TCE aging, geological conditions, pumping rates, and pressures. Through the partnership, Environmental Science graduate students come to RMSC, and develop sophisticated 3-D models based on actual remediation activities. The students get to participate in an excellent learning opportunity, and help accelerate RMSC's remediation process. In addition, RMSC gains valuable information from the student's models.

Solid Waste Recycling Program

For many years, RMSC's recycling efforts consisted of individual schemes scattered throughout the facility. However in 1996, the Air Force made a request for RMSC to develop a more aggressive approach to landfill reduction. The company was tasked with meeting a 50% solid waste reduction goal for 1997, based on 1992 landfill metrics.

To develop the Solid Waste Recycling program, RMSC and union representatives teamed together to identify and implement several alternatives to landfilling. Paper products, as well as packaging materials, provided opportunities for much of the waste diversion. Wood waste is given away to employees as well as to not-for-profit organizations during RMSC's Free Wood Wednesday events. The company sends several semi-trailer loads of large wooden crates to Mexico, where the wood is donated to under-privileged families. In addition, broken crates are shredded for landscaping and compost use. The company implemented several programs where returnable shipping crates are routinely sent back to suppliers and customers. Styrofoam packaging peanuts are also given away to a local shipping company which gives RMSC employees a discount for their patronage. The company keeps employees and contractors up-to-date on the latest recycling guidelines via a training video. This video is shown annually at team meetings throughout the facility, as well as at employee and contractor orientations.

RMSC's Solid Waste Recycling program reduced the company's dependency on local landfills by more than 50% in the past few

years. This program generates in excess of $2,000 monthly, and provides steady employment for six disabled employees who collect the recyclables. RMSC's use of cross-functional teams will also ensure further expansion of the program.

Statistical Process Control

In 1993, RMSC formed the Process Improvement Group to identify the company's manufacturing processes, and review how they contribute to product performance, quality, cost, and schedule. The group, consisting of engineering and manufacturing specialists, also looked at how other companies set up their process control methodologies. Based on RMSC's culture, the group initiated a seven-step Statistical Process Control (SPC) process.

The SPC process analyzes critical and major processes for implementing process control charting. As shown graphically in Figure 3-3, the process uses various process improvement tools (e.g., flow charts, process maps, pareto charts, design of experiments, regression descriptive statistics) to accomplish this task. In 1996, the group was renamed the Product, Process, and Performance Improvement Group (PPPIG) to reflect its new direction. PPPIG now focuses on six sigma tools and techniques; process characterization and metrics; and sigma card scoring to predict the potential for defects on new product designs.

RMSC's seven-step SPC process was presented to the operations manager who embraced the concept, and took responsibility for implementing it into various process centers. In addition, PPPIG developed an SPC system manual; a process control technical handbook, and an SPC training curriculum. The group now interacts with engineering and manufacturing teams to provide training and guidance.

Facilities

Creform Tooling

In 1996, RMSC began using Creform Tooling to build its material handling equipment and parts presentation devices. Creform is a plastic-coated, steel-pipe material which comes in a variety of colors.

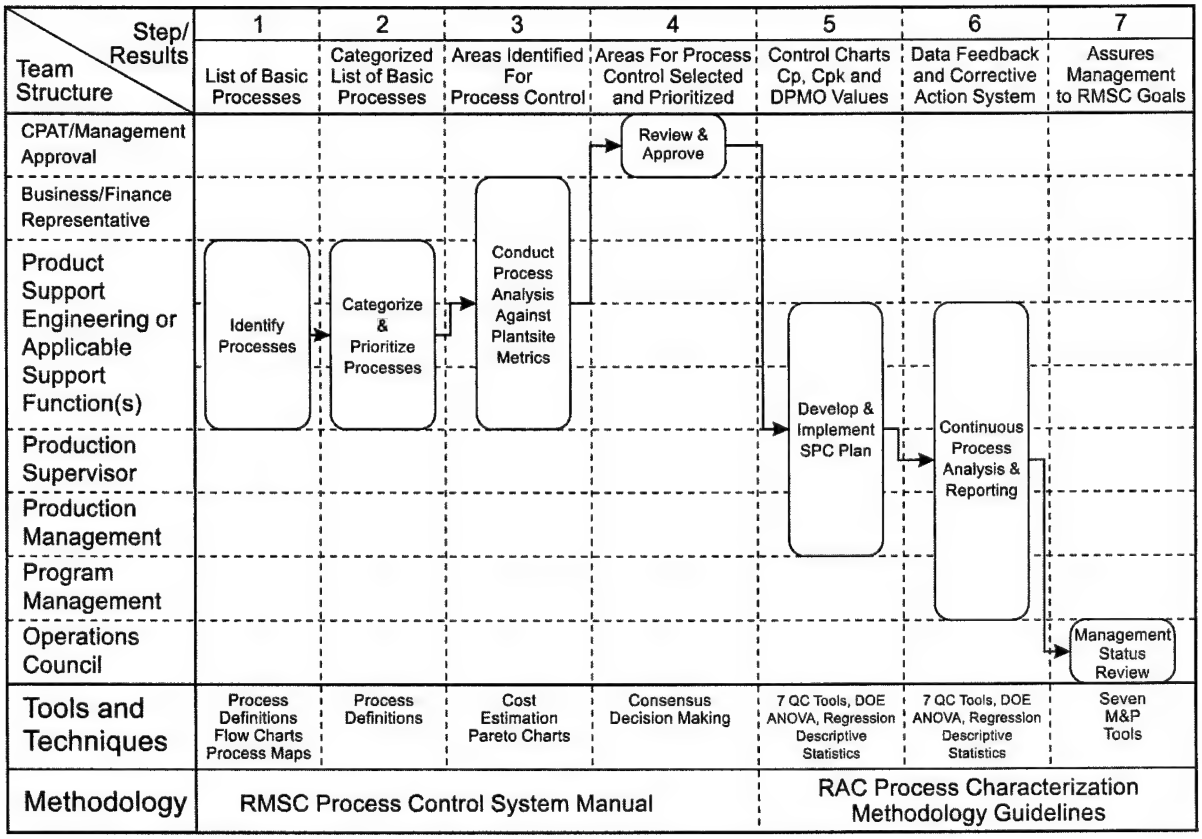


Figure 3-3. Seven Step Process

The material is purchased in standard lengths; is easy to cut; and can be conductive or non-conductive depending on the desired application. Sections of creform are joined by using bolt-together fasteners or plastic glue-on fasteners.

By using Creform Tooling, RMSC can create devices that are mobile, reusable, easily reconfigured, and relatively inexpensive. These characteristics are well suited for the agile manufacturing atmosphere at RMSC. In addition, the material's uniformity simplifies the design and assembly phases, and reduces the amount of stock and tools needed. Creform products have proven to be at least 50% directly reusable from its original design intent, and the material itself is 95% reusable.

The following shows a material cost comparison for building a typical workstation cart:

STAINLESS TUBE

- Labor cost for Design phase is five hours
- Labor cost for Assembly phase is 27 hours
- Material cost is $1,144
- Value of reusable material is $80

STEEL TUBE PAINTED

- Labor cost for Design phase is five hours
- Labor cost for Assembly phase is 27 hours
- Material cost is $558
- Value of reusable material cost is $80

CREFORM

- Labor cost for Design phase is three hours
- Labor cost for Assembly phase is 11 hours
- Material cost is $887
- Value of reusable material is $416

Assuming $65 per hour for engineering and $25 per hour for labor, the total cost for building the workstation cart is $2,144 for stainless tube; $1,558 for steel tube painted; and $1,357 for creform. Annual savings (total cost minus value of reusable material) is $2,064 for stainless tube; $1,478 for steel tube painted; and $941 for creform. Between 1996 and 1998, RMSC produced 180 devices per year, and realized a savings of $830 per device. Creform Tooling enabled the company to obtain an annual savings of $149,400 during this time period.

Environmental, Health, and Safety Strategic Plan and Goals Process

The EH&S Strategic Plan creates the foundation for RMSC's EH&S management system, and provides the vision, mission, and guiding strategic objectives for the company's EH&S programs. The plan is also aligned with the five focus areas (customer satisfaction, competitiveness, quality, people development, and financial performance) of Vision 2000.

A cross-functional team of key stakeholders implemented the EH&S Strategic Plan as a long-term strategic method to guide EH&S programs into the future as well as provide consistent, annual EH&S objectives and priorities. A weekly EH&S conference call is used to communicate common problems between 80 sites, and an annual corporate conference is held to promote the sharing of knowledge among all Raytheon sites. A Missile Systems EH&S Quality Leadership council is also being established to emulate the philosophy of the RMSC Leadership Team. The EH&S Strategic Plan translates the corporate objectives into strategic elements and processes.

Based on the principles of ISO-14000, the EH&S Strategic Plan forms the basis of the annual goal planning processes, and helps provide year-to-year business consistency. Goals of the EH&S Business Plan include:

- 100% process efficiency
- 100% employee productivity
- Reduce solid waste generation by 20% (1997 baseline)
- Reduce industrial waste generation by 30% (1997 baseline)
- Reduce hazardous waste generation by 15% (1997 baseline)
- Reduce energy costs by 30% to 50% (1993 baseline)
- Eliminate manufacturing use of MDA and ozone depleting chemicals by the year 2000
- Attain overall environmental compliance rating for legacy sites (quarterly report card)
- Reduce accident rate
- Contribute to company's cost reduction goal

RMSC is still in the process of aligning business activities, and integrating four different business cultures. Although the number of business units is still fluctuating, the EH&S Strategic Plan will help the company establish goals and objectives.

Final Assembly Checkout

RMSC uses a Final Assembly Checkout (FACO) facility to perform all phases of production on missile systems, including final assembly and test procedures. This approach eliminates the need to ship missile systems to secondary locations. The FACO facility is adequately distanced from other manufac-

turing plants and office buildings, the Tucson International Airport, and the surrounding community. RMSC can deliver a completely assembled, all up round (AUR) missile system to its customers from this site. AUR means the missile is fully fueled and has an explosive warhead.

The company's Tucson site was established for missile production in the early 1950s with sufficient land to house a FACO facility. Specific distances were established and maintained to allow for the handling, installation, test, and storage of missile ordnance. The FACO facility, in conjunction with nearby subassembly and missile production factories, is essential to manufacturing, assembling, inspecting, testing, and delivering AURs to customers from a single site. This arrangement reduces support personnel and equipment; improves logistics; decreases cycle times; and lowers product costs. RMSC's FACO facility includes 24 magazines, with more than 2,000 square feet of storage and additional smaller magazines. Delivery and access by truck, rail, and air are readily available.

Maximization of Carbon Loading Efficiency for Soils Remediation

RMSC developed DPE as an enhancement to its pump-and-treat remediation system. The technique involves evacuating air (vapor extraction) from the casing of a pumping groundwater extraction well. The pumping lowers the water level in the well and exposes solvent-contaminated soils to the air. The vacuum also causes the solvents to evaporate. As the air is sucked from the well, the vapor is pulled out and captured within GACs. The GACs are connected, in tandem, to the vapor extraction blower, and enables the extracted solvent to maximize the carbon loading efficiency for soils remediation (Figure 3-4). Geologic conditions at RMSC favor DPE due to the existence of the clay bed at the top of the aquifer, which traps non-aqueous phase liquids. The removal rate of TCE is approximately 120 pounds per month.

During the maximization stage, vapor is discharged into the primary carbon vessels until the vapor concentration of the vessel effluent is the same concentration as the vapor entering the vessel. This process ensures the maximum saturation of the GACs. Next, the primary vessel is removed, and the partly-saturated secondary vessel is moved into the primary vessel's position. A new carbon vessel is placed in the secondary position, and the process starts over. The spent primary carbon vessel is shipped offsite for regeneration.

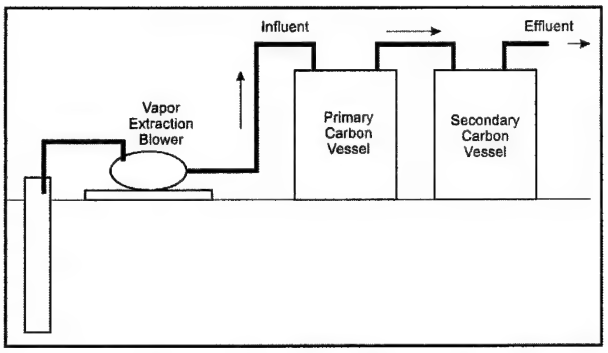


Figure 3-4. Maximization of Carbon Loading Efficiency for Soils Remediation

RMSC removes thousands of pounds of TCE and other waste solvents from the ground each year by this method. The consumption of GACs is the highest cost item associated with operating vapor extraction systems. Because the carbon vessels are connected in tandem, the primary carbon vessel can be fully saturated with the solvent vapor. The secondary vessel absorbs the excess vapor when the primary vessel becomes fully saturated, and prevents discharging to the atmosphere (where the vapor would become an air pollutant).

Activated carbon is used in roll-offs of 10,000 pounds and 20,000 pounds. The carbon supplier replaces the saturated units with dry units, and RMSC assumes no liability for this material. The cost of carbon is $1.25 per pound. The maximization loading efficiency of GAC usage is essential in controlling remediation costs. Loading efficiency is defined as the number of pounds of solvent which can be captured in a given weight of solvent before complete breakthrough occurs. For example, if 300 pounds of solvent are captured in 1,000 pounds of carbon, then the loading efficiency is 30%. Loading efficiency is also proportional to the influent concentration and to the duration of exposure. High concentrations and long exposure periods give higher loading rates.

Waste Segregation Process

The spent hazardous chemical collection process, previously done at RMSC, was inefficient and created opportunities for regulatory non-compliance, incorrect treatment, and storage problems due to chemical incompatibilities. The chemical handlers would collect the spent material; transport them to the hazardous waste treatment facility; and wait for environmental managers to instruct them on the correct way to process each container. The manufacturing process and/or constituents of the hazardous material

dictated the method of disposal or treatment. As a result, backlogs of unprocessed material were common, and created safety and regulatory liabilities for the company.

To resolve this situation, RMSC's Waste Operations Team created a documentation process that uses labeling codes and a corresponding work instruction list. The users place labeling codes on all waste containers (e.g., small tote pans, 55-gallon drums) before the chemical handlers pick up the spent material. These labels identify the chemical constituents and the process in which they were used. After transporting the materials to the treatment facility, the chemical handlers reference the codes to the work instruction list to determine the proper segregation, treatment, and/or disposal procedures in accordance with RMSC and regulatory policies. The chemical handlers can now process the spent chemicals without managerial guidance. RMSC's documentation process helps reduce non-compliance, incorrect treatment, and storage problems. In addition, the process ensures that waste is handled according to environmental regulations as soon as it arrives at the treatment facility.

The chemical handling procedure list contains instructions for 90% of all chemicals used at RMSC. Since implementing this documentation process, RMSC increased efficiency and safety at its hazardous waste treatment facility, decreased company liabilities, improved labor performance of the chemical handlers, and reduced the time required for oversight by environmental managers by 25%.

Wastewater Strategies Team

Built in 1977, RMSC's centralized Industrial Wastewater Treatment Plant (IWTP) was designed to provide large volumes of high-quality reclaimed water for reuse in numerous on-site wet processes, while concurrently treating the resulting wastewater and chemical wastes generated from these processes. Piping systems transfer these by-products from the company to the IWTP. Currently, the Plant filtrates and processes approximately 170 gallons of wastewater per minute. The solids are collected and disposed as hazardous waste (about 20 cubic yards per month). The treated water is collected and discharged to the Pima County Treatment Facility at a rate of two million gallons per month. The IWTP has six holding tanks, each with a capacity of three million gallons.

However, current and anticipated transition activities (e.g., moving major wet processes to other Raytheon facilities) may decrease or eliminate future demands for the IWTP's services. This loading reduction will substantially reduce the cost-effectiveness of the Plant in managing the company's remaining regulated process wastewater and/or chemical wastes. In response, RMSC set up the Wastewater Strategies Team to simplify the treatment processes and its supporting infrastructure. The team will also revise and implement the necessary management practices for wastewater and chemical management. These efforts will help reduce the long-term operating and maintenance costs of the treatment plant. An important part of the strategy is to make current/future processes environmentally friendly and/or implement closed-loop, zero-discharge recycling systems. Besides reducing costs, these recycling systems will accelerate the Air Force's and RMSC's P2 initiative long-term goals and objectives.

RMSC anticipates an annual savings between $600,000 and $1 million, and projects that the Air Force will save $400,000 in supplemental funds. The company is changing its focus from compliance to P2, largely due to new technologies such as the ion exchange at point of generation, which should be in place by June 1999. RMSC will also reduce legal and operating liabilities as a result of implementing a simplified infrastructure.

Logistics

On-Hand Inventory Level

In 1991, RMSC initiated a program to reduce its production On-Hand Inventory Level to a three-month quantity. This change was the result of government contractual requirements, which set five months as the maximum on-hand inventory level. Customer-provided progress payments to RMSC are not authorized beyond this limit.

RMSC researched the defense and aerospace industries to determine the best-in-class On-Hand Inventory Levels. Based on this level of 2.7 months, RMSC set its own inventory goal at three months. Over the past year, the company reduced its On-Hand Inventory Level from 4.8 months to the goal level of three months.

Since implementing the three-month On-Hand Inventory Level, RMSC reduced resource investments for on-hand inventory; enhanced the utilization of customer-provided progress payments; simplified management reviews; became compliant with the DOD's Material Management Accounting Standards; and heightened visibility to individual programs. The company plans to continue operating at this on-hand inventory level.

Phalanx Life Cycle Support

Currently, the process for furnishing spares and supplying support for the Fleet's Phalanx weapon systems involves many subcontractors and support activities. This process can take numerous days to fulfill orders requested by sailors. RMSC is proposing a simplified approach which will provide 24-hour availability to the Fleet, and a response time of hours instead of days. The company is designating its Louisville, Kentucky facility as the point-of-contact for these services.

The Phalanx's Life Cycle Support covers 350 systems, and involves many operations including maintenance, field service, training, documentation, engineering, and logistics. RMSC's goal is to provide a single, full-service contract at one price, that will service the Phalanx weapon systems for the life of the program. The proposal consists of establishing a Phalanx website where customers can access information and services, such as parts ordering, training, technical assistance, and news. Fleet support will consist of on-board technical assistance; battle group sparing; installation and checkout; and corrective maintenance. Depot support will include overhaul, repairs, and spare equipment. Parts sparing will use commercial delivery methods so items can be tracked worldwide and delivered within hours.

RMSC's proposal will provide responsive support at less cost; use commercial practices for support functions; create organizational efficiencies through consolidation; and offer the Navy an innovative opportunity to support the Phalanx program. The company projects a 10% to 15% cost savings over the present process. The Phalanx Life Cycle Support will also establish a simplified infrastructure; give the Navy a single point-of-contact; improve logistics support; and provide better service to the customer.

Subcontract Management

Approximately 80% of the materials used by the Phalanx and RAM Launcher programs are provided by subcontractors. The IPTs of these programs recognized that in order for RMSC to become a world-class provider, the company needed to implement a more disciplined approach for material procurement. The teams identified three key elements which needed to be addressed: material requisition release date; purchase order placement date; and subsequent receipt of the purchased material.

In the past, the practice of managing these key elements by using existing reports proved unsuccessful, due to the structure and format of the reports being generated. Gathering all the information for these reports was also time consuming. To resolve these problems, RMSC developed a planner code. Each part, listed on the purchase bill of material, is identified to the user via a planner code. This approach enables users to generate a team report that only lists those materials needed by a specific team. These team reports are generated weekly, and provide a schedule activity requirement list, based on task priority, which allows RMSC to monitor the activity levels for each team's materials. The company also developed Subcontractor Management Reviews, which is a process for determining and monitoring the supplier's production readiness. By using these reviews, RMSC can identify situations up-front which may hinder the subcontractor's ability to deliver on-time materials. This process also allows for additional time, so corrective actions can be implemented before a shortage becomes a major problem.

Prior to adopting these changes, RMSC had significant money tied up in residual material for the Phalanx and RAM Launcher programs. At any given time, late procurement requisitions and purchase orders each ran well over 500, and parts late-to-dock were in excess of 350. After implementing the new practices over a 12-month period, RMSC reduced its residual material by 80%. Procurement requisitions, purchase orders, and parts late-to-dock numbered less than 70 each. By applying these simple concepts to the procurement process of the Phalanx and RAM Launcher programs, RMSC has been able to provide these products to its customers consistently ahead of schedule.

Supplier Base Reduction

The supplier base at RMSC had grown quite large due to the Raytheon/Hughes merger and the restructuring of the company's product and manufacturing lines. To address this situation, RMSC established a Supplier Base Reduction process to effectively control and reduce its supplier base. This process focuses on using supplier certifications, supplier improvements, and economic support of agile manufacturing to streamline the base. The company also considers economic procurement efforts, inventory management, and on-time/quality delivery issues of each supplier.

RMSC set up Technology Roadmaps to identify preferred suppliers; utilize a supplier-managed inventory where feasible; and eliminate inactive or poor performing suppliers. The company also wanted to increase business transactions with those suppliers who demonstrated timeliness, reasonable costs, and quality performance. Technology teams were set up to develop preferred supplier lists, which include perfor-

mance history. The information on suppliers is readily available electronically to all RMSC personnel. Meetings are held with suppliers to ensure that purchase orders are fully understood, and oversight is provided as required. Records of supplier quality, over the past two years, are also available on-line and have been effectively used to streamline the supplier base. RMSC reduced the number of production suppliers from 3,119 in 1995 to 1,742 in 1997. The company's goal for 1998 is 1,480.

Besides reducing the administrative workload associated with a larger base, RMSC's process provided the company with a more responsive and economically viable supplier base. The Supplier Base Reduction process also improved the hardware acceptance rates and on-time delivery measures, and provided cost benefits to RMSC.

Technical Data Export Certification

The International Traffic in Arms Regulations (ITAR) govern technical data export requirements for defense products. ITAR states that defense-related technical data can only be exported if a valid export license exists or an ITAR exemption is applicable. Per these regulations, technical data exports must be documented including any ITAR exemptions, and the information must be retained for five years from the date of export.

Over the years, RMSC's program offices used various non-standardized forms, certificates, and certification processes to handle technical data export situations. In addition, the means of designating an authorized individual to certify the technical data exports was inconsistent. Typically, the designation was not determined by a single, focal point-of-contact. As a result, RMSC initiated Technical Data Export Certification to standardize the forms, certifications, and handling procedures for exporting technical data. Only those individuals, authorized by senior RMSC contracts management, may authorize an export. These individuals must meet specific criteria before being designated as authorized signatories.

RMSC's process ensures that technical data exports can only take place if a valid export license or an ITAR exemption exists. The process also enables the company to properly document and retain the export information per government regulations.

Value Engineering Process

In 1988, RMSC initiated an active Value Engineering process on its AMRAAM program to implement low-cost design changes. The primary Value Engineering objectives were to maintain system performance and lower unit costs. The secondary objectives were to improve system performance and increase reliability. As a result of the Value Engineering process, the AMRAAM program's overall missile costs were reduced, enabling the Air Force to fulfill its missile inventory requirements.

The Value Engineering process allows RMSC to progressively update a program's design and incorporate current parts technology. This approach avoids obsolete part procurements, and facilitates missile and productivity improvements. RMSC's customers have been very supportive of the Value Engineering process. Low-cost design changes have financially benefitted RMSC, its suppliers, and the Joint Strike Project Office. Since 1995, AMRAAM Value Engineering projects are credited with a cost savings of more than $9 million. These changes focused primarily on parts reduction including COTS and PEMs.

The Value Engineering process promotes a cooperative teaming environment, and enables RMSC to reduce unit costs, increase reliability, and improve system performance on projects. Recent pricing agreements have also provided RMSC and its suppliers with incentives to develop and implement future cost reductions.

Management

Best Practices Web Page

When RMSC decided to host a Best Manufacturing Practices survey, the company searched for a way to identify those practices which were potential candidates for presentation. The solution was to develop a web page as part of the company's Intranet website. Here, candidate topics could be submitted, reviewed, and approved as survey presentations. The company expected approximately 30 practices to be submitted, but received more than 100 within a one-month period.

The Best Practices web page soon grew into an asset that proved useful beyond its intended purpose. The company also added other features, such as search engines, which expanded the capabilities of this database. The web page's shell is written in HTML. Information is submitted in Microsoft Word, and then converted to the HTML format. The company is planning on using this web page for various functions including a training aid; a way to recognize employees and teams for superior accomplishments; and a clearinghouse to showcase RMSC's capabilities, creativeness, and strengths since the Hughes merger.

The Best Practices web page enables RMSC to identify and collect noteworthy practices throughout the company. RMSC hopes to springboard this tool into a way of making breakthroughs in new and developing processes.

Contractor Self-Governance

RMSC and the local DCMC Program Quality representatives for the AMRAAM program began exploring the idea of Contractor Self-Governance. This approach would shift many of the oversight duties of the local DCMC to RMSC for the AMRAAM program. In April 1996, the AMRAAM Program Executive Officer at Wright-Patterson Air Force Base nominated the approach. As a result, a one-year experiment was initiated in July 1996 to test the feasibility of Contractor Self-Governance.

The DCMC Quality and RMSC AMRAAM Quality organizations jointly conducted the Contractor Self-Governance experiment. A plan with detailed procedures was used to identify which areas of the AMRAAM program would be assumed by the contractor. These experimental areas were restricted to AMRAAM-dedicated functions. Any area with a common tie to another program was excluded from the experiment. Metrics were set up to measure these areas, and DCMC provided RMSC with training on quality procedures. DCMC also performed monthly audits on the experiment's progress.

After one year, the Contractor Self-Governance experiment indicated no significant audit issues and no degradation in the quality of the AMRAAM program. The experiment also received positive feedback from internal and external customers. Encouraged by the results, the groups adopted a continuation plan which discontinued the monthly reporting and auditing requirements of the initial experiment.

Although Contractor Self-Governance basically had no effect on RMSC's process on the AMRAAM program, this approach did enhance the company's awareness of its responsibility for quality. The experiment also enabled DCMC to redirect its workforce to other projects.

Employee Recognition Day

A valued and appreciated workforce is critical to the success and future of any business. In 1996, RMSC expanded its Employee Recognition program by adding an annual Employee Recognition Day. On this designated day, the company recognizes all employee contributions which led to the successful achievement of enterprise goals.

During Employee Recognition Day, organized group activities (free lunches served by management, publicized achievements) are held throughout the company. This day celebrates the accomplishments of all employees, as well as reinforces the company's Recognition and Rewards program. Teams and departments are invited to display their accomplishments on kudo boards for all to see. In December 1997, the latest Employee Recognition Day was held in conjunction with the 50th anniversary of Hughes and the consolidation of Hughes Missile, Texas Instruments, and Raytheon. The event was also a celebration which successfully brought closure to the Hughes Tucson facility and launched the start of the RMSC Tucson facility.

Employee Recognition Day provides a unique opportunity for the company to recognize employee contributions and achievements, as well as improve communications between management and employees. The response to the latest celebration exceeded all expectations. Teams and departments displayed more than 700 kudo boards, and attendance surpassed 7,000.

Hourly Technical Membership

In the past, IPTs at RMSC consisted mostly of managerial and technical experts. Few hourly employees were asked to join. RMSC, in conjunction with its TEDCs, decided that hourly employees should be equally represented on all IPTs. The reasoning was two-fold. Since most products are assembled by hourly employees, their input during the early phases of development could greatly reduce costs during production. In addition, all employees become more dedicated and productive when they are treated as part of the team.

RMSC chose a TEDC that had a fully integrated team, and used it as a model for others. The methodology and results of this prototype team were publicized throughout the company. Management also encouraged hourly employees to participate on IPTs, and other TEDCs recommended technicians from their group.

By encouraging Hourly Technical Membership, RMSC realized significant results. Hourly employees have become stakeholders in the company's products. Many potential problems are now resolved before the product reaches the production stage. The company also reduced rework labor by 10% to 20%; rework material by 15%; cycle times by 10% to 40%; and overtime by 10%.

Internet Website

RMSC's Internet website is an excellent way for the company to communicate information, provide services, and highlight accomplishments. Two aspects of this website are the Human Resources and the Media Relations web pages.

The Human Resources web page provides a simple and easy way for Internet visitors to obtain initial information on the company. Here, job openings at RMSC are posted, and visitors can make requests for additional information via e-mail. Like other companies in the defense market, RMSC gets numerous requests for photographs and videos. The Media Relations web page enables the company to furnish visitors with up-to-date information and graphics pertaining to its missile weapon systems. This web page contains high-solution JPG images of all product lines manufactured by RMSC, as well as short MPEG and AVI digital movies that display the systems in operation. These graphics can be previewed and/or downloaded by Internet visitors for public use. If a sharper image of a digital movie is needed, visitors can request a video tape (typically in Beta format) from the company. The Media Relations web page provides RMSC with a cost savings of $3.00 per photograph and $5.00 per movie. With requests numbering in the thousands per year, these savings can be significant.

RMSC's Internet website has other features and services, including historical background on the company; information related to community relations; links to other websites; and the automated rotation of images on pages so frequent visitors will see a constantly changing website. Potential vendors of RMSC can also access pertinent information and initiate contact. RMSC's Internet website was set up by enlisting the services of a small, start-up web page company in the local area. This company offered RMSC a fixed price of $25,000 to run and maintain the website with unlimited update allowances.

Materials and Processes Engineering

In 1997, RMSC combined the Applications Engineering group and the Laboratory group to form a single Materials and Processes (M&P) Engineering team. The Applications Engineering group had consisted of degreed engineers who interfaced with customers, provided expertise on M&P selection, participated on IPTs, and performed failure analyses. The Laboratory group had consisted mostly of non-degreed technicians who operated behind the scenes and provided engineering support to the Applications Engineering group. Although some interaction existed between the groups, each tended to stay in their respective domains which prevented an effective, synergistic-working relationship from developing.

The creation of a single functional M&P team enabled RMSC to effectively deploy M&P resources, and leverage the talents and abilities of its employees. Cross-training was enhanced, which led to new opportunities and challenges for employees. RMSC also streamlined the M&P Engineering team's effort by developing a single, company-level practice to govern M&P selection and control. By distributing and sharing the workload, the boundaries between applications engineer and laboratory technician became blurred. As a result, the M&P Engineering team's productivity improved as well as its turnaround times and customer satisfaction levels. Increased visibility with customers and management enabled employees to pursue new avenues of advancement.

The M&P Engineering team can handle a 20% increase in workload by using a streamlined, multifunctional staff. This approach has been beneficial to RMSC as well as to the employees.

Process Oriented Contract Administrative Services Program Management

The Process Oriented Contract Administrative Services (PROCAS) program fosters ways to improve the working relationships between contractors and the government. Managed by DCMC, this program was mandated in 1994. In 1997, RMSC implemented the PROCAS Program Management as a way to maximize the opportunities within the PROCAS program.

The company appointed an internal representative to interact with DCMC's PROCAS manager. In addition, a joint PROCAS Action Team was established to organize and provide oversight of PROCAS activities within RMSC. This team is responsible for discussing problems, developing strategies, and tasking teams to work on areas identified as problems or high risk. The PROCAS Action Team reports to a senior-level management team consisting of executives from RMSC, DCMC, and the Defense Contract Auditing Agency (DCAA). RMSC also developed a PROCAS team worksheet to aid the tasking teams in fulfilling their assignments. This worksheet enables tasking teams to identify goals and plans of action, as well as provides them with a means of tracking progress and lessons learned. As a result, the amount of time that a team spends on a task has been reduced from two years to less than six months.

Since implementing the PROCAS Program Management, RMSC has realized significant benefits in its missile programs. This proactive approach refined many processes, increased the efficiency of operations at RMSC, and resulted in substantial cost savings. Communications among RMSC, DCMC, and DCAA also improved under the PROCAS Program Management.

Proposals and Media Support Process Teaming

The primary function of RMSC's Proposal and Media Support Services department is to support proposal publications. Other responsibilities include multimedia presentations, document reproduction, graphics design, electronic publishing, and other related services. Recent restructuring efforts have significantly reduced the department's personnel without decreasing its workload. In addition, the workload fluctuates from less than ten proposal projects to as much as 40 per year. RMSC wanted to develop a flexible organizational structure that could acclimate to the department's changing needs.

To accomplish this goal, RMSC shifted its Proposal and Media Support Services department from a traditional, vertical organizational structure to a highly flexible one. This flexible structure permits the rapid buildup and disbandment of Special Project Support Teams as proposal, presentation, graphic, and multimedia needs arise. In addition, the approach provides true integrated and shared support functions that are supported by cross-functional teaming. The goals are to maximize available resources; eliminate bottlenecks and excessive paper handling; address business cycle fluctuations; serve the needs of the customer; retain core competencies; eliminate redundancies; and maximize opportunities for cost savings. During peak load times, the company outsources some of the support services.

The Proposals and Media Support Process Teaming focuses on customer needs, utilizes department capabilities, and eliminates the need to draw resources from core service providers or fill voids with contract labor. Under the new process, RMSC reduced the number of department managers from 31 to 20, decreased supervisory positions by 61%, and increased in-house production staff by 12%. More than 75% of special support services are now transferred directly to the benefitting organizations.

Purchased Material Inspection

In 1994, RMSC developed an automated Purchased Material Inspection (PMI) system which can capture inspection/test requirements and results. This system operates at minimal cost, and creates a common focus and plan for component inspection and test information.

RMSC's system consists of modules that record inspection/test requirements and results, as well as defect material results and resolutions. Other functions include scheduling material to MRP requirements, and providing inquiry capability for individual programs by contract. The PMI system uses COTS software, and replaces an in-house developed system that required extensive continual support. RMSC estimates its annual savings at more than $6,600.

The PMI system is managed and administered at one source, but has been implemented at various offsite facilities. This arrangement reduces cycle times by two days. Communication with legacy systems also exists. The PMI system is adjustable to changing business practices, provides accountability of quality material, and details the efficiency of the receiving and inspection/test processes at RMSC.

Software Quality Assurance Tools

In 1993, RMSC's Software Quality Assurance group developed an application which uniformly reports the software quality metrics across multiple programs. This data collection and reporting application standardizes the metrics of project and process data, while reducing the report preparation time. Criteria developed for this application was derived from ISO and Capabilities Maturity Model metric elements. RMSC uses a database to identify defects, defect types, projects, and organizations as well as associated Software Quality Assurance manpower and funding projections. These activity-based projections enable users to centrally collect and report common metrics.

The Software Quality Assurance tools offer consistent, prompt access and storage of software quality assurance metrics, and provide reports to customers and project/management personnel. Defect data permits users to tailor their quality assurance efforts for best results. Compliance data is available for projects, organizations, and activity metrics. Problem areas, risks, and corrective actions can also be derived from database information. By using this application, RMSC expects to make its Software Quality Assurance functions more proactive and process-focused.

Streamlining Interconnect Test Requirements

Per RMSC specifications, all interconnect products purchased for production use were required to undergo Group B and/or Group C testing. The company, however, began examining these test requirements as an acquisition reform initiative. After reviewing the process, RMSC determined that these tests were non-value added procedures which lengthened the lead-times for interconnects purchased for production use. Historical data from these tests also indicated that the suppliers of the interconnects had optimized the design of these parts, and implemented manufacturing process controls to ensure that the interconnects would perform to RMSC's requirements.

In February 1998, RMSC began waiving Group B and/or Group C testing requirements for interconnect products used on all programs. By streamlining these requirements, the company reduced the costs and lead times associated with procuring interconnect products. As of August 1998, RMSC achieved a cost savings of more than $80,000.

University Liaison Program Plan

RMSC has developed a company-wide, coordinated program plan whose purpose is to build partnerships with schools, colleges, universities, and its employees to leverage technology, stimulate life-long learning, and nurture diversity. Using a team of engineering and human resources personnel, the University Liaison Program plan focuses on recruiting, education, diversity, and technology. This team has also developed an Involvement Continuum as a way to reach more graduates from targeted schools, increase the number of minorities in engineering disciplines, and support RMSC's Small and Disadvantaged Business program. The ultimate goal is to make RMSC an employer of choice.

Various university liaison programs have existed in the legacy companies that make up RMSC. However, this recently-developed program plan is designed to manage and leverage relationships across the entire, expanded company. In addition, the plan assures maximum effectiveness in directing RMSC's resources toward college and pre-college, thereby obtaining greater return on its investments in human and financial terms.

RMSC's efforts in this area have already been successful. The company obtained additional state funding and fostered a common, statewide master of science degree in engineering at three Arizona state universities. Once the University Liaison Program plan is funded, RMSC will be poised to achieve its goals of creating partnerships with selected universities; assisting them with funding and guidance in nurturing highly-qualified graduates; expanding summer intern and co-op experiences to better prepare students for future industry employment; and achieving significant joint efforts with historically black and Hispanic colleges, universities, and institutions.

Video Teleconferencing Center

Video teleconferencing is a method of visually and audibly linking multiple conference sites by using a standard dial-up telephone system. Cameras are used to send images of the attendees as well as to transmit slide images, documents, and video tapes to the linked sites. Over the years, RMSC's evolving video teleconferencing capability has improved its communications with other sites and reduced travel expenses.

The origin of video teleconferencing at the Tucson site began in 1981 when the facility was known as Hughes Missile Systems. The first link was set up between the Manufacturing Business Unit in Tucson, Arizona and the Engineering Business Unit in Canoga Park, California — a distance of 500 miles. The insight demonstrated by Hughes (now RMSC) to use video teleconferencing was ahead of its time. In 1981, video teleconferencing was limited to black and white, used a frame-capture system, and required 45 seconds to transmit a picture. The company advanced to a full color version with a five-second frame rate in 1983, and a simulated live TV version with a four-second frame rate in 1986. By 1987, all of its business units were linked. Because of Hughes' early pioneering efforts to pursue this technology, video teleconferencing has become an efficient and effective business tool. This readily-available COTS product is now used throughout the world.

Today, Raytheon has approximately 114 rooms within the corporation that are equipped with video teleconferencing capability and compatible dial-up systems. Eight Video Teleconferencing Centers (VTCs) are located at the Tucson site: two in executive rooms, one each in engineering and the Knowledge Center Southwest, and four dedicated to the AMRAAM, Tomahawk, AIM-9X, and TOW programs. These VTCs are available to all levels of personnel who have special communication needs.

Video teleconferencing continues to pay great dividends to RMSC. These benefits include improving communications through immediate face-to-face meetings; achieving a higher level of participation from

employees; producing cost savings through reduced travel time; minimizing delays by encouraging on-the-spot decision making; and developing closer ties between the company and the customer.

Vision 2000

Vision 2000 is a visual alignment tool that provides information on RMSC's vision, goals, and accountabilities. This shared vision is part of everything that represents RMSC; forms the basis for its strategic plans and annual goals; and provides the framework for managing its enterprise. Figure 3-5 shows RMSC's Vision 2000 chart.

After merging with General Dynamics in 1993 and consolidating the missile design/manufacturing lines from five sites to a single one at Tucson, the new organization needed a common focus. Vision 2000 was developed by a cross-functional team of employees who worked closely with management for six months. Since then, this tool has become the overarching guide for change and improvement at RMSC.

Vision 2000 enables RMSC to concentrate on the five focus areas (customer satisfaction, competitiveness, quality, people development, and financial performance) that are important to the company's overall business. Results in these focus areas have been impressive, including decreases in manufacturing cycle time, and a 50% reduction in defects per year for the past four years. Because of its significant impact on improving all aspects of company performance, this alignment tool has been implemented by many of RMSC's customer groups, as well as adopted as a strategic planning tool by Davis Monthan Air Force Base. Vision 2000 has proven to be an effective and flexible tool for organizational alignment, and can adjust to new initiatives as they are employed in the five focus areas.

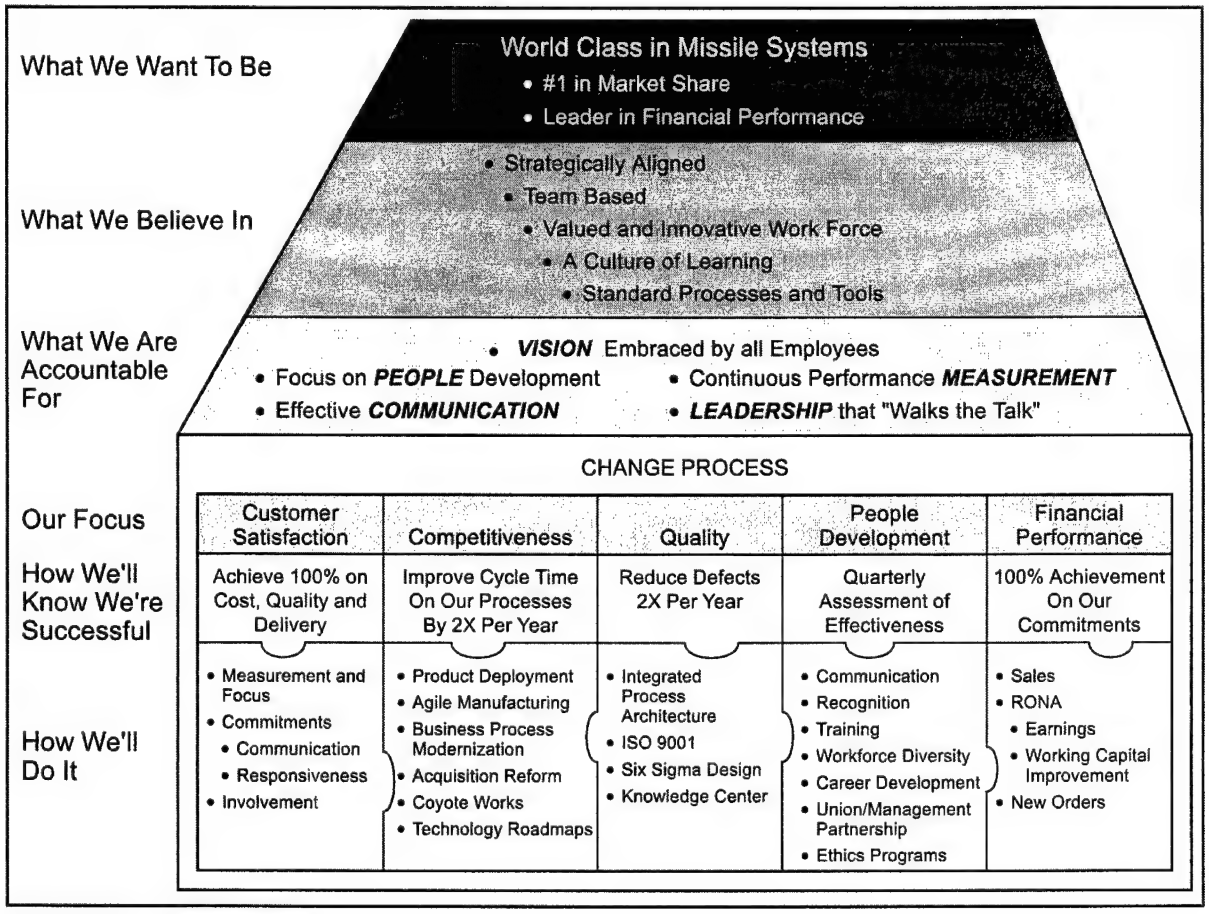


Figure 3-5. Vision 2000

Appendix A

Table of Acronyms

Acronym	Definition
6DOF	Six Degrees of Freedom
ACS	Automated Calibration System
AFP44	Air Force Plant 44
AMF	Advanced Modular Factory
AMRAAM	Advanced Medium Range Air-to-Air Missile
AP2I	Acquisition Pollution Prevention Initiative
ATE	Automated Test Equipment
AUR	All Up Round
BST	Boundary Scan Test
CAB	Corrective Action Board
CAD	Computer Aided Design
CAIV	Cost as an Independent Variable
CDRL	Contract Data Requirements List
CEP	Career Enrichment Program
CIMS	Components Information Management System
CITIS	Contractor Integrated Technical Information Service
COTS	Commercial-Off-The-Shelf
CPA	Cooperative Program Agreement
CPAT	Corrective and Preventive Action Team
CRB	Change Review Board
CSP	Chemical Strategies Partnership
DCAA	Defense Contract Auditing Agency
DCC	Dependent Care Connection
DCE	Dichloroethylene
DCMC	Defense Contract Management Command
DFE	Design For Environment
DMS	Diminishing Manufacturing Sources
DOD	Department of Defense
DOE	Design of Experiment
DPE	Dual Phase Extraction
EDI	Electronic Data Interchange
EH&S	Environmental, Health, and Safety
EISM	Enterprise Information Systems Management
EOSPA	Electro-Optic Sensors and Precision Assembly
EPA	Environmental Protection Agency
ESCo	Energy Services Company
ESPC	Energy Saving Performance Contracting
ESSM	Evolved Sea Sparrow Missile
FACO	Final Assembly Checkout

Acronym	Definition
GAC	Granular Activated Carbon
GPM	Gallons Per Minute
GSI	Government Source Inspection
GSS	Government Source Surveillance
HAP	Hazardous Air Pollutant
HHW	Household Hazardous Waste
HMA	Hybrid Microelectronic Assembly
IFS	Integrated Flight Simulation
IMP	Integrated Master Planning
IPA	Integrated Process Architecture
IPD	Integrated Product Development
IPPD	Integrated Product and Process Development
IPT	Integrated Product Team
IRAD	Independent Research and Development
IT	Information Technology
ITAR	International Traffic in Arms Regulations
IWTP	Industrial Wastewater Treatment Plant
JACME^{2}T	Joint Arizona Consortium - Manufacturing and Engineering Education for Tomorrow
KCC	Key Control Characteristic
KCDS	Key Characteristic Designation System
KCSW	Knowledge Center Southwest
KPC	Key Product Characteristic
LAI	Lean Aerospace Initiative
LAMOTT	Lay A Missile On The Table
LEAP	Lightweight Exo-Atmospheric Projectile
LEM	Lean Enterprise Model
MDA	Methylenedianiline
MOST	Missile Object-oriented Simulation Tool
MOU	Memorandum of Understanding
M&P	Materials and Processes
MRP	Manufacturing Resource Planning
MVP	Manufacturing Verification Program
NATO	North Atlantic Treaty Organization
NESHAP	National Emission Standard for Hazardous Air Pollutants
P2	Pollution Prevention
PCAT	Process Capability Analysis Tool
PDM	Product Data Management
PEM	Plastic Encapsulated Microcircuit
PI	Performance Index
PIM	Product Information Management

Acronym	Definition
PIP	Process Improvement Program
PMI	Purchased Material Inspection
P/MMT	Parts/Material Management Team
POC	Point of Contact
PPPIG	Product, Process, and Performance Improvement Group
PPR	Production Plan Review
PPV	Parts Presentation Vehicle
PROCAS	Process Oriented Contract Administrative Services
QFD	Quality Function Deployment
RAM	Rolling Airframe Missile
REPC	Raytheon Electronics Packaging Consortium
RMSC	Raytheon Missile Systems Company
SEMP	Strategic Energy Management Plan
SEPP	Software Engineering Practices and Procedures
SLIC	Supplier Liaison Information Control
SPC	Statistical Process Control
SPI	Single Process Initiative
TCE	Trichloroethylene
TDP	Technical Data Package
TEDC	Test Equipment Design Center
TIES	Totally Integrated Enterprise System
TOW	Tube-launched, Optically-tracked, Wire-guided
TRB	Technical Review Board
UCAB	Unified Community Advisory Board
UUT	Unit Under Test
VOC	Volatile Organic Contaminant
VTC	Video Teleconferencing Center
WIP	Work In Progress

Appendix B

BMP Survey Team

Team Member	Activity	Function
Larry Robertson (812) 854-5336	**Crane Division** **Naval Surface Warfare Center** Crane, IN	**Team Chairman**
Cheri Spencer (301) 403-8100	**BMP Center of Excellence** College Park, MD	**Technical Writer**
Caryl Lummis (301) 403-8100	**BMP Center of Excellence** College Park, MD	**Technical Writer**
Paula Hauser (812) 854-6649	**Naval Surface Warfare Center** Crane, IN	**Technical Writer**
	Team 1	
Nick Keller (812) 854-5331	**Naval Surface Warfare Center** Crane, IN	**Team Leader**
Don Hill (317) 306-3781	**Raytheon Systems Company** Indianapolis, IN	
Don Livingston (812) 854-5157	**Naval Surface Warfare Center** Crane, IN	
Jack Tamargo (707) 642-4267	**BMP Satellite Center** Vallejo, CA	
	Team 2	
Bob Harper (301) 403-8100	**BMP Center of Excellence** College Park, MD	**Team Leader**
Bob Cale (518) 266-5300	**Watervliet Arsenal** Watervliet, NY	
Mike Bond (909) 273-5324	**Naval Warfare Assessment Station** Corona, CA	
Dan Carlson (309) 782-6475	**Headquarters, U.S. Army** Industrial Operations Command Rock Island, IL	

Team 3

Larry Halbig (317) 306-3838	**Raytheon Systems Company** Indianapolis, IN	**Team Leader**
Anne Marie SuPrise (301) 403-8100	**BMP Center of Excellence** College Park, MD	
Brian Willoughby (301) 403-8100	**BMP Center of Excellence** College Park, MD	
Jack McInnis (703) 271-9055	**Production Technology, Inc.** Arlington, VA	

Team 4

Darrel Brothersen (319) 295-3768	**Rockwell Collins Avionics & Communications** Cedar Rapids, IA	**Team Leader**
Dan Fazekas (703) 271-9055	**Production Technology, Inc.** Arlington, VA	
Mark Hancock (301) 403-8100	**BMP Center of Excellence** College Park, MD	
Elaine Geisler (909) 273-4991	**Naval Warfare Assessment Center** Corona, CA	

Team 5

Mark Barclay (732) 323-1182	**Naval Air Warfare Center** Lakehurst, NJ	**Team Leader**
Rose Thun (301) 403-8100	**BMP Center of Excellence** College Park, MD	
Nick Tambakis (301) 403-8100	**BMP Center of Excellence** College Park, MD	
Mike Cisneros (909) 273-5471	**Naval Warfare Assessment Center** Corona, CA	

Team 6

Rick Purcell (301) 403-8100	**BMP Center of Excellence** College Park, MD	**Team Leader**
Charlie Minter (301) 403-8100	**BMP Center of Excellence** College Park, MD	
Greta Gadson (703) 271-9055	**Production Technology, Inc.** Arlington, VA	
Sarah Mitchell (703) 271-9055	**Production Technology, Inc.** Arlington, VA	

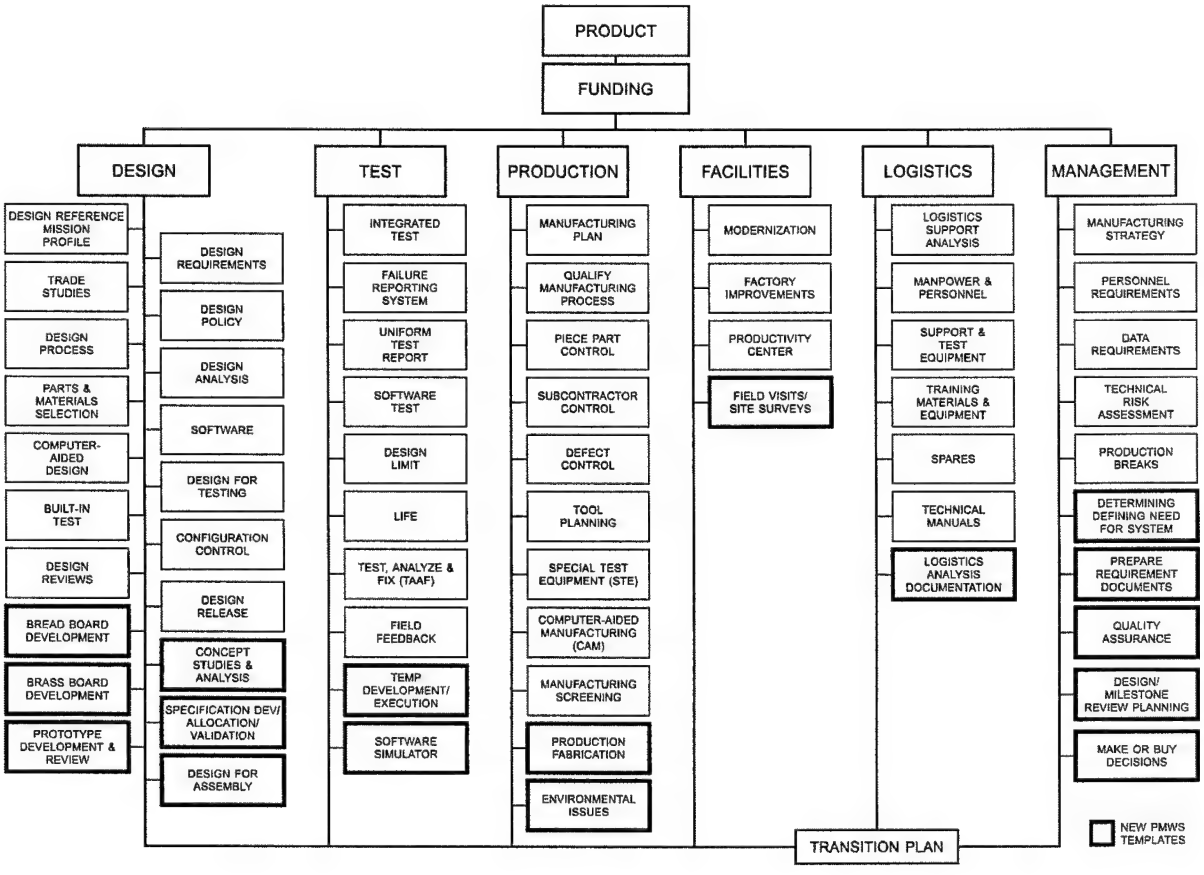
Appendix C

Critical Path Templates and BMP Templates

This survey was structured around and concentrated on the functional areas of design, test, production, facilities, logistics, and management as presented in the Department of Defense 4245.7-M, *Transition from Development to Production* document. This publication defines the proper tools—or templates—that constitute the critical path for a successful material acquisition program. It describes techniques for improving the acquisition process by addressing it as an *industrial* process that focuses on the product's design, test, and production phases which are interrelated and interdependent disciplines.

The BMP program has continued to build on this knowledge base by developing 17 new templates that complement the existing DOD 4245.7-M templates. These BMP templates address new or emerging technologies and processes.

"CRITICAL PATH TEMPLATES FOR TRANSITION FROM DEVELOPMENT TO PRODUCTION"

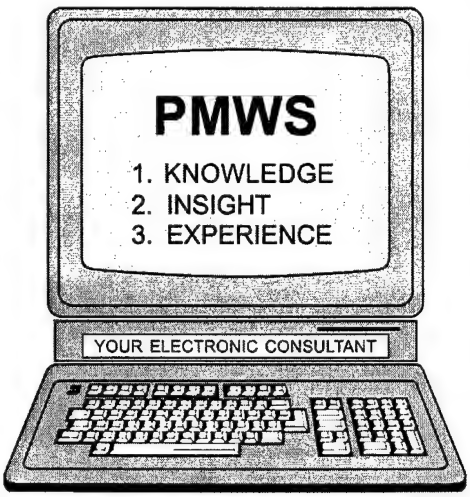


Appendix D

BMPnet and the Program Manager's WorkStation

The BMPnet, located at the Best Manufacturing Practices Center of Excellence (BMPCOE) in College Park, Maryland, supports several communication features. These features include the Program Manager's WorkStation (**PMWS**), electronic mail and file transfer capabilities, as well as access to Special Interest Groups (SIGs) for specific topic information and communication. The BMPnet can be accessed through the World Wide Web (at http://www.bmpcoe.org), through free software that connects directly over the Internet or through a modem. The PMWS software is also available on CD-ROM.

PMWS provides users with timely acquisition and engineering information through a series of interrelated software environments and knowledge-based packages. The main components of PMWS are KnowHow, SpecRite, the Technical Risk Identification and Mitigation System (TRIMS), and the BMP Database.



KnowHow is an intelligent, automated program that provides rapid access to information through an intelligent search capability. Information currently available in KnowHow handbooks includes Acquisition Streamlining, Non-Development Items, Value Engineering, NAVSO P-6071 (Best Practices Manual), MIL-STD-2167/2168 and the DoD 5000 series documents. KnowHow cuts document search time by 95%, providing critical, user-specific information in under three minutes.

SpecRite is a performance specification generator based on expert knowledge from all uniformed services. This program guides acquisition personnel in creating specifications for their requirements, and is structured for the build/approval process. SpecRite's knowledge-based guidance and assistance structure is modular, flexible, and provides output in MIL-STD 961D format in the form of editable WordPerfect® files.

TRIMS, based on DoD 4245.7-M (the transition templates), NAVSO P-6071, and DoD 5000 event-oriented acquisition, helps the user identify and rank a program's high-risk areas. By helping the user conduct a full range of risk assessments throughout the acquisition process, TRIMS highlights areas where corrective action can be initiated before risks develop into problems. It also helps users track key project documentation from concept through production including goals, responsible personnel, and next action dates for future activities.

The **BMP Database** contains proven best practices from industry, government, and the academic communities. These best practices are in the areas of design, test, production, facilities, management, and logistics. Each practice has been observed, verified, and documented by a team of government experts during BMP surveys.

Access to the BMPnet through dial-in or on Internet requires a special modem program. This program can be obtained by calling the BMPnet Help Desk at (301) 403-8179 or it can be downloaded from the World Wide Web at http://www.bmpcoe.org. To receive a user/e-mail account on the BMPnet, send a request to helpdesk@bmpcoe.org.

Appendix E

Best Manufacturing Practices Satellite Centers

There are currently nine Best Manufacturing Practices (BMP) satellite centers that provide representation for and awareness of the BMP program to regional industry, government and academic institutions. The centers also promote the use of BMP with regional Manufacturing Technology Centers. Regional manufacturers can take advantage of the BMP satellite centers to help resolve problems, as the centers host informative, one-day regional workshops that focus on specific technical issues.

Center representatives also conduct BMP lectures at regional colleges and universities; maintain lists of experts who are potential survey team members; provide team member training; identify regional experts for inclusion in the BMPnet SIG e-mail; and train regional personnel in the use of BMP resources such as the BMPnet.

The nine BMP satellite centers include:

California

Chris Matzke
BMP Satellite Center Manager
Naval Warfare Assessment Division
Code QA-21, P.O. Box 5000
Corona, CA 91718-5000
(909) 273-4992
FAX: (909) 273-4123
cmatzke@bmpcoe.org

Jack Tamargo
BMP Satellite Center Manager
257 Cottonwood Drive
Vallejo, CA 94591
(707) 642-4267
FAX: (707) 642-4267
jtamargo@bmpcoe.org

District of Columbia

Chris Weller
BMP Satellite Center Manager
U.S. Department of Commerce
14th Street & Constitution Avenue, NW
Room 3876 BXA
Washington, DC 20230
(202) 482-8236/3795
FAX: (202) 482-5650
cweller@bxa.doc.gov

Illinois

Thomas Clark
BMP Satellite Center Manager
Rock Valley College
3301 North Mulford Road
Rockford, IL 61114
(815) 654-5515
FAX: (815) 654-4459
adme3tc@rvcux1.rvc.cc.il.us

Iowa

Bruce Coney
Program Manager
Iowa Procurement Outreach Center
200 East Grand Avenue
Des Moines, IA 50309
(515) 242-4888
FAX: (515) 242-4893
bruce.coney@ided.state.ia.us

Louisiana

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(423) 576-5532
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tgraham@bmpcoe.org

Appendix F

Navy Manufacturing Technology Centers of Excellence

The Navy Manufacturing Sciences and Technology Program established the following Centers of Excellence (COEs) to provide focal points for the development and technology transfer of new manufacturing processes and equipment in a cooperative environment with industry, academia, and Navy centers and laboratories. These COEs are consortium-structured for industry, academia, and government involvement in developing and implementing technologies. Each COE has a designated point of contact listed below with the individual COE information.

Best Manufacturing Practices Center of Excellence

The Best Manufacturing Practices Center of Excellence (BMPCOE) provides a national resource to identify and promote exemplary manufacturing and business practices and to disseminate this information to the U.S. Industrial Base. The BMPCOE was established by the Navy's BMP program, Department of Commerce's National Institute of Standards and Technology, and the University of Maryland at College Park, Maryland. The BMPCOE improves the use of existing technology, promotes the introduction of improved technologies, and provides non-competitive means to address common problems, and has become a significant factor in countering foreign competition.

Point of Contact:
Mr. Ernie Renner
Best Manufacturing Practices Center of Excellence
4321 Hartwick Road
Suite 400
College Park, MD 20740
(301) 403-8100
FAX: (301) 403-8180
ernie@bmpcoe.org

Center of Excellence for Composites Manufacturing Technology

The Center of Excellence for Composites Manufacturing Technology (CECMT) provides a national resource for the development and dissemination of composites manufacturing technology to defense contractors and subcontractors. The CECMT is managed by the Great Lakes Composites Consortium and represents a collaborative effort among industry, academia, and government to develop, evaluate, demonstrate, and test composites manufacturing technologies. The technical work is problem-driven to reflect current and future Navy needs in the composites industrial community.

Point of Contact:
Mr. James Ray
Center of Excellence for Composites Manufacturing Technology
c/o GLCC, Inc.
103 Trade Zone Drive
Suite 26C
West Columbia, SC 29170
(803) 822-3708
FAX: (803) 822-3710
jrglcc@glcc.org

Electronics Manufacturing Productivity Facility

The Electronics Manufacturing Productivity Facility (EMPF) identifies, develops, and transfers innovative electronics manufacturing processes to domestic firms in support of the manufacture of affordable military systems. The EMPF operates as a consortium comprised of industry, university, and government participants, led by the American Competitiveness Institute under a CRADA with the Navy.

Point of Contact:
Mr. Alan Criswell
Electronics Manufacturing Productivity Facility
One International Plaza
Suite 600
Philadelphia, PA 19113
(610) 362-1200
FAX: (610) 362-1290
criswell@aci-corp.org

National Center for Excellence in Metalworking Technology

The National Center for Excellence in Metalworking Technology (NCEMT) provides a national center for the development, dissemination, and implementation of advanced technologies for metalworking products and processes. The NCEMT, operated by Concurrent Technologies Corporation, helps the

Navy and defense contractors improve manufacturing productivity and part reliability through development, deployment, training, and education for advanced metalworking technologies.

Point of Contact:
Mr. Richard Henry
National Center for Excellence in Metalworking Technology
c/o Concurrent Technologies Corporation
100 CTC Drive
Johnstown, PA 15904-3374
(814) 269-2532
FAX: (814) 269-2501
henry@ctc.com

Navy Joining Center

The Navy Joining Center (NJC) is operated by the Edison Welding Institute and provides a national resource for the development of materials joining expertise and the deployment of emerging manufacturing technologies to Navy contractors, subcontractors, and other activities. The NJC works with the Navy to determine and evaluate joining technology requirements and conduct technology development and deployment projects to address these issues.

Point of Contact:
Mr. David P. Edmonds
Navy Joining Center
1250 Arthur E. Adams Drive
Columbus, OH 43221-3585
(614) 688-5096
FAX: (614) 688-5001
dave_edmonds@ewi.org

Energetics Manufacturing Technology Center

The Energetics Manufacturing Technology Center (EMTC) addresses unique manufacturing processes and problems of the energetics industrial base to ensure the availability of affordable, quality, and safe energetics. The focus of the EMTC is on process technology with a goal of reducing manufacturing costs while improving product quality and reliability. The EMTC also maintains a goal of development and implementation of environmentally benign energetics manufacturing processes.

Point of Contact:
Mr. John Brough
Energetics Manufacturing Technology Center
Indian Head Division
Naval Surface Warfare Center
101 Strauss Avenue
Building D326, Room 227
Indian Head, MD 20640-5035
(301) 744-4417
DSN: 354-4417
FAX: (301) 744-4187
mt@command.ih.navy.mil

Institute for Manufacturing and Sustainment Technologies

The Institute for Manufacturing and Sustainment Technologies (iMAST), was formerly known as Manufacturing Science and Advanced Materials Processing Institute. Located at the Pennsylvania State University's Applied Research Labortory, the primary objective of iMAST is to address challenges relative to Navy and Marine Corps weapon system platforms in the areas of mechnical drive transmission techologies, materials science technologies, high energy processing technologies, and repair technology.

Point of Contact:
Mr. Henry Watson
Institute for Manufacturing and Sustainment Technologies
ARL Penn State
P.O. Box 30
State College, PA 16804-0030
(814) 865-6345
FAX: (814) 863-1183
hew2@psu.edu

National Network for Electro-Optics Manufacturing Technology

The National Netowork for Electro-Optics Manufacturing Technology (NNEOMT), a low overhead virtual organization, is a national consortium of electro-optics industrial companies, universities, and government research centers that share their electro-optics expertise and capabilities through project teams focused on Navy requirements. NNEOMT is managed by the Ben Franklin Technology Center of Western Pennsylvania.

Point of Contact:
Dr. Raymond V. Wick
National Network for Electro-Optics Manufacturing Technology
One Parks Bend
Box 24, Suite 206
Vandergrift, PA 15690
(724) 845-1138
FAX: (724) 845-2448
wick@nneomt.org

Gulf Coast Region Maritime Technology Center

The Gulf Coast Region Maritime Technology Center (GCRMTC) is located at the University of New Orleans and focuses primarily on product developments in support of the U.S. shipbuilding industry. A sister site at Lamar University in Orange, Texas focuses on process improvements.

Point of Contact:
Dr. John Crisp, P.E.
Gulf Coast Region Maritime Technology Center
University of New Orleans
College of Engineering
Room EN-212
New Orleans, LA 70148
(504) 280-5586
FAX: (504) 280-3898
jncme@uno.edu

Manufacturing Technology Transfer Center

The focus of the Manufacturing Technology Transfer Center (MTTC) is to implement and integrate defense and commercial technologies and develop a technical assistance network to support the Dual Use Applications Program. MTTC is operated by Innovative Productivity, Inc., in partnership with industry, government, and academia.

Point of Contact:
Mr. Raymond Zavada
Manufacturing Technology Transfer Center
119 Rochester Drive
Louisville, KY 40214-2684
(502) 452-1131
FAX: (502) 451-9665
rzavada@mttc.org

Appendix G

Completed Surveys

As of this publication, 109 surveys have been conducted and published by BMP at the companies listed below. Copies of older survey reports may be obtained through DTIC or by accessing the BMPnet. Requests for copies of recent survey reports or inquiries regarding the BMPnet may be directed to:

Best Manufacturing Practices Program
4321 Hartwick Rd., Suite 400
College Park, MD 20740
Attn: Mr. Ernie Renner, Director
Telephone: 1-800-789-4267
FAX: (301) 403-8180
ernie@bmpcoe.org

1985	Litton Guidance & Control Systems Division - Woodland Hills, CA
1986	Honeywell, Incorporated Undersea Systems Division - Hopkins, MN (Alliant TechSystems, Inc.) Texas Instruments Defense Systems & Electronics Group - Lewisville, TX General Dynamics Pomona Division - Pomona, CA Harris Corporation Government Support Systems Division - Syosset, NY IBM Corporation Federal Systems Division - Owego, NY Control Data Corporation Government Systems Division - Minneapolis, MN
1987	Hughes Aircraft Company Radar Systems Group - Los Angeles, CA ITT Avionics Division - Clifton, NJ Rockwell International Corporation Collins Defense Communications - Cedar Rapids, IA UNISYS Computer Systems Division - St. Paul, MN (Paramax)
1988	Motorola Government Electronics Group - Scottsdale, AZ General Dynamics Fort Worth Division - Fort Worth, TX Texas Instruments Defense Systems & Electronics Group - Dallas, TX Hughes Aircraft Company Missile Systems Group - Tucson, AZ Bell Helicopter Textron, Inc. - Fort Worth, TX Litton Data Systems Division - Van Nuys, CA GTE C^3 Systems Sector - Needham Heights, MA
1989	McDonnell-Douglas Corporation McDonnell Aircraft Company - St. Louis, MO Northrop Corporation Aircraft Division - Hawthorne, CA Litton Applied Technology Division - San Jose, CA Litton Amecom Division - College Park, MD Standard Industries - LaMirada, CA Engineered Circuit Research, Incorporated - Milpitas, CA Teledyne Industries Incorporated Electronics Division - Newbury Park, CA Lockheed Aeronautical Systems Company - Marietta, GA Lockheed Corporation Missile Systems Division - Sunnyvale, CA Westinghouse Electronic Systems Group - Baltimore, MD General Electric Naval & Drive Turbine Systems - Fitchburg, MA Rockwell International Corporation Autonetics Electronics Systems - Anaheim, CA TRICOR Systems, Incorporated - Elgin, IL
1990	Hughes Aircraft Company Ground Systems Group - Fullerton, CA TRW Military Electronics and Avionics Division - San Diego, CA MechTronics of Arizona, Inc. - Phoenix, AZ Boeing Aerospace & Electronics - Corinth, TX Technology Matrix Consortium - Traverse City, MI Textron Lycoming - Stratford, CT

1991	*Resurvey of Litton Guidance & Control Systems Division* - Woodland Hills, CA
	Norden Systems, Inc. - Norwalk, CT
	Naval Avionics Center - Indianapolis, IN
	United Electric Controls - Watertown, MA
	Kurt Manufacturing Co. - Minneapolis, MN
	MagneTek Defense Systems - Anaheim, CA
	Raytheon Missile Systems Division - Andover, MA
	AT&T Federal Systems Advanced Technologies and AT&T Bell Laboratories - Greensboro, NC and Whippany, NJ
	Resurvey of Texas Instruments Defense Systems & Electronics Group - Lewisville, TX
1992	Tandem Computers - Cupertino, CA
	Charleston Naval Shipyard - Charleston, SC
	Conax Florida Corporation - St. Petersburg, FL
	Texas Instruments Semiconductor Group Military Products - Midland, TX
	Hewlett-Packard Palo Alto Fabrication Center - Palo Alto, CA
	Watervliet U.S. Army Arsenal - Watervliet, NY
	Digital Equipment Company Enclosures Business - Westfield, MA and Maynard, MA
	Computing Devices International - Minneapolis, MN
	(Resurvey of Control Data Corporation Government Systems Division)
	Naval Aviation Depot Naval Air Station - Pensacola, FL
1993	NASA Marshall Space Flight Center - Huntsville, AL
	Naval Aviation Depot Naval Air Station - Jacksonville, FL
	Department of Energy Oak Ridge Facilities (Operated by Martin Marietta Energy Systems, Inc.) - Oak Ridge, TN
	McDonnell Douglas Aerospace - Huntington Beach, CA
	Crane Division Naval Surface Warfare Center - Crane, IN and Louisville, KY
	Philadelphia Naval Shipyard - Philadelphia, PA
	R. J. Reynolds Tobacco Company - Winston-Salem, NC
	Crystal Gateway Marriott Hotel - Arlington, VA
	Hamilton Standard Electronic Manufacturing Facility - Farmington, CT
	Alpha Industries, Inc. - Methuen, MA
1994	Harris Semiconductor - Melbourne, FL
	United Defense, L.P. Ground Systems Division - San Jose, CA
	Naval Undersea Warfare Center Division Keyport - Keyport, WA
	Mason & Hanger - Silas Mason Co., Inc. - Middletown, IA
	Kaiser Electronics - San Jose, CA
	U.S. Army Combat Systems Test Activity - Aberdeen, MD
	Stafford County Public Schools - Stafford County, VA
1995	Sandia National Laboratories - Albuquerque, NM
	Rockwell Defense Electronics Collins Avionics & Communications Division - Cedar Rapids, IA
	(Resurvey of Rockwell International Corporation Collins Defense Communications)
	Lockheed Martin Electronics & Missiles - Orlando, FL
	McDonnell Douglas Aerospace (St. Louis) - St. Louis, MO
	(Resurvey of McDonnell-Douglas Corporation McDonnell Aircraft Company)
	Dayton Parts, Inc. - Harrisburg, PA
	Wainwright Industries - St. Peters, MO
	Lockheed Martin Tactical Aircraft Systems - Fort Worth, TX
	(Resurvey of General Dynamics Fort Worth Division)
	Lockheed Martin Government Electronic Systems - Moorestown, NJ
	Sacramento Manufacturing and Services Division - Sacramento, CA
	JLG Industries, Inc. - McConnellsburg, PA
1996	City of Chattanooga - Chattanooga, TN
	Mason & Hanger Corporation - Pantex Plant - Amarillo, TX
	Nascote Industries, Inc. - Nashville, IL
	Weirton Steel Corporation - Weirton, WV
	NASA Kennedy Space Center - Cape Canaveral, FL
	Department of Energy, Oak Ridge Operations - Oak Ridge, TN

1997	Headquarters, U.S. Army Industrial Operations Command - Rock Island, IL
	SAE International and Performance Review Institute - Warrendale, PA
	Polaroid Corporation - Waltham, MA
	Cincinnati Milacron, Inc. - Cincinnati, OH
	Lawrence Livermore National Laboratory - Livermore, CA
	Sharretts Plating Company, Inc. - Emigsville, PA
	Thermacore, Inc. - Lancaster, PA
	Rock Island Arsenal - Rock Island, IL
	Northrop Grumman Corporation - El Segundo, CA
	(Resurvey of Northrop Corporation Aircraft Division)
	Letterkenny Army Depot - Chambersburg, PA
	Elizabethtown College - Elizabethtown, PA
	Tooele Army Depot - Tooele, UT
1998	United Electric Controls - Watertown, MA
	Strite Industries Limited - Cambridge, Ontario, Canada
	Northrop Grumman Corporation - El Segundo, CA
	Corpus Christi Army Depot - Corpus Christi, TX
	Anniston Army Depot - Anniston, AL
	Naval Air Warfare Center, Lakehurst - Lakehurst, NJ
	Sierra Army Depot - Herlong, CA
	ITT Industries Aerospace/Communications Division - Fort Wayne, IN
	Raytheon Missile Systems Company - Tucson, AZ